HISTORY

OF THE

PROGRESS

AND

PRESENT STATE

OF

ANIMAL CHEMISTRY.

BY

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IN THREE VOLUMES.

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HISTORY

OF

ANIMAL CHEMISTRY.

LIFE.

The Vital Principle.

THAT life is a material principle, and confequently
fubject to the laws of chemical affinities, has been
afferted by feveral philofophers; but although no fatisfac-
tory explanation has yet been given refpecting it's action,
or mode of producing it's various effects, when confidered
in a chemical view, it will not be deviating from the ob-
ject of the prefent work to give a few of the principal
opinions that have been held of it's nature.

The exiftence of a living principle in the animal body
has been acknowledged from the earlieft ages. At firft it
was looked upon as being particularly connected with the
blood; for, having obferved that the body was deprived
of life by great evacuations of blood, either in battle or by
accidental caufes, it was natural to conclude that this fluid
conveyed the living principle out of the wound, and pro-

duced death. This was the idea of Mofes, and the reafon why that legiflator prohibited the Ifraelites from eating blood. "Therefore I faid unto the children of Ifrael, Ye fhall eat the blood of no manner of flefh; for the life of all flefh is the blood thereof. I will even fet my face againft that foul that eateth blood; for the life of the flefh is in the blood." Homer gives death the epithet purple, πορφυρεος θανατος: and Virgil alludes to it when he fays, *purpuream vomit ille animam.* Empedocles and Critias believed life to be the blood itfelf.

Upon examining the opinions of the ancient fects of philofophers, on the immateriality and materiality of the foul, it would appear, that the immaterialifts, confidering all the fubtile and invifible fluids as not fubject to the laws of matter, thought they had difcovered amongft them the origin of the foul, whilft fome of them feem to have con- founded the foul with the living principle. Thus Hera- clitus looked upon the foul, or intelligent principle, as in- corporeal, or an exhalation; Parmenides, that it was fire; Epithormus, that it was extracted from the fun; and An- axagoras, Anaximenes, and Archelaus, that is was a fub- tile air. Hippo afferted it to be a vapour; for, according to him, humidity was the principle of all things; and Boëcius, that it was compofed of air and fire. Marcus Antoninus the Stoic was perfuaded of it's great refemblance to the wind, and Critolaus imagined that its effence was a fifth fub- ftance. Many of the moderns have fuppofed the foul ori- ginates from the feminal liquor; that at firft it is merely a vegetating principle, like unto that of a plant, but after- ward, on becoming more perfect, it acquires a fenfitive property, and is at laft rendered reafonable by the divine cooperation.

Pythagoras had imagined the foul to be detached from the air, and had invented an *anima mundi,* from

which the fouls of men were emanations: but as the reciprocal action of the foul and the body upon each other was not eafily explained on the fuppofition of immateriality, Plato feems to have improved on the idea Plato. of Pythagoras, by propofing that of a *plaftic nature*, a kind of intermediary living principle connecting the foul and body; and this plaftic principle was acknowledged even by Hippocrates and Ariftotle, although differently modified by various fects. Ariftotle the peripatetic, and Ariftotle. the fcholar of Plato, afferts the foul to be the firft entelechia of the natural organic body, having the living principle under it's direction. It has three faculties; the nutritive, the fenfitive, and the rational. The firft is that in which life is the only acting principle. The fecond is that by which feeling is produced. The third is peculiar to man, and is that part of him which knows and judges. This intellect is either an intellectum agens vel patiens. The firft may be feparated from the body, and is immortal: the other is perifhable. Life is a permanence of the foul, according to this philofopher, retained by the natural heat, and the principle of this heat is in the heart. Galen was Galen. much attached to the doctrine of Ariftotle, and made commentaries full of erudition on the works of that philofopher. Among the Arabs, Avicenna and Averroes were the principal who commented on the doctrine of the Stagyrite. Among the phyficians of Italy that followed the fame doctrine was Andrew Cefalpinus, firft phyfician to Clement VIII; and it ended with Corringius.

Leucippus, Democritus, and Epicurus were real mate- Epicurus. rialifts. They were of opinion there was nothing in exiftence but body, and that the principle of life and intelligence are only modifications of matter; that they arife from the difpofition of the atoms in organized bodies, in the fame manner as the flefh, the blood, and other fenfible parts.

Lactantius, who believed the foul likewife corporeal, after having examined all the various opinions of philofophers on the fubject of the effence of which the foul is compofed, and having regarded them all as uncertain, acknowledges, however, they are not without fome fhare of truth—our foul, or the principle of life, being in the blood, in the heart, and in the fpirit—but that it is impoffible to exprefs the nature which is the refult, being more eafy to fee the operations of it than to define it.

It would appear, therefore, all the ancients had fome idea of a living principle which animates the corporeal

Plutarch. machine; and this is afferted by Plutarch, who ought to know beft the fentiments of the ancients, having given a treatife on their opinions. He fays, as being acknowledged by all of them, that fpirit is only a fubtile matter, and our foul, which is the air, keeps us alive; and in this manner all the world contains fpirit and air, which are only two names fignifying the fame thing.

The anima. mundi of Pythagoras, the φυσις of Hippocrates, and the πνευμα of the author of De Mundo, was afterwards defcribed by the name of *calidum innatum*, as expreffing the vital principle: and fome of the firft reftorers of letters adopted the fame opinion: and during a confiderable part of the feventeenth century, a regular fyftem prevailed, by which the vital principle was reckoned the efficient caufe of generation and exiftence in all animals and plants. It then took the name of *anima vegetans*.

Paracelfus. Paracelfus changed this term, in his hypothetical and fanciful method of reafoning, for that of *fidereal fpirit*, which, according to his opinion, was equally independent of the body and the mind, but defcended from the firmament, as the rational foul proceeded from the deity. Van Helmont, who thought he improved upon the fyftem of his mafter Paracelfus, fuggefted the theory of the Archeüs, without venturing to affert the unity of the rational and

living fouls. The actions of the Archeüs were after-
wards reduced by Stahl to the operations of the *rational* Stahl.
foul; but, according to Dr. Ferriar, Defcartes appears to
have been the firft modern philofopher who rejected the
feparate exiftence of the vital principle, under all denomi-
nations. He availed himfelf of the progrefs that was
made in the nervous phyfiology not long before, by Wil-
lis and others, to form an hypothefis of the vital functions,
founded on the fuppofition of the nervous fluid or ani-
mal fpirits, which was the language of that period.
The doctrine of Stahl made confiderable progrefs ; and
the fuppofition of a rational power, or vis medicatrix
naturæ, which directs all the actions of the body both in
health and difeafe, became univerfal ; and for a long time
the terms of nature, fenfitive foul, and vital principle, were
employed without much oppofition. The exiftence of a
nervous fluid was now affumed independently of the fen-
fitive foul, to explain the appearances of fenfation and vo-
luntary motion.

About the middle of the laft century, when Haller was
afferting his theory of the *vis infita,* and *vis nervea,* Dr.
Whytt of Edinburgh attempted a reformation of the Whytt.
Stahlian doctrine, which excluded the independent living
principle. He fuppofes the foul to be prefent in different
parts of the brain at the fame time, while he confiders this
foul as immaterial and unextended.

Some philofophers at length began to imagine that
matter might acquire vitality, in confequence of a certain
organization, and amongft thefe were Buffon and Hoff- Buffon.
mann. But while no fingle hypothefis refpecting the vital
principle prevailed generally, two theories appeared, which
more particularly engaged the attention. Dr. Monro gives Monro.
his explanation of the *intellectus agens* in the body, by fay-
ing, that the power which created all things, which gave
life to animals, continues to act upon and to maintain all,

by the unceasing influence of a living principle pervading
the universe, the nature of which our faculties are inca-
pable of duly comprehending. The other theory was that
of John Hunter, who revived the idea of the blood being
endued with the living principle. This opinion, as obferved
before, is not only to be found in the writings attributed to
Mofes, but in modern times it had been afferted by Harvey,
Hoffmann, and more particularly by Huxham, who even
mentions the red globules as the peculiar feat of life. The
proofs which John Hunter brings of the life of the blood
are the following : 1. It unites living parts when effufed
between them. 2. The blood becomes vafcular, like other
living parts. 3. It's temperature, as it flows from the
vein, is always equal, in the moft oppofite temperatures to
which the body can bear expofure. 4. It is capable of
being acted upon by a ftimulus, as is the cafe when it
coagulates. 5. The laft direct proof of the life of the
blood is the nourifhment and prefervation of life in para-
lytic limbs.

Goodwyn, who endeavoured to confider the fubject of
vitality in a manner different from what it had been,
taking the living body when all the accidental figns of life
are removed, and applying to it thofe external powers
which really do reftore them, then attending to the place
and circumftances of their firft operation, and the imme-
diate effects they produce, was led to examine the effen-
tial quality of life, and confequently to the means of di-
ftinguifhing it from death. This phyfician is of opinion,
that the heart is the great feat of the principle of life, in all
the more perfect animals ; and that the contraction of the
heart with the ordinary ftimulus is the only mark of the
prefence of this principle ; that when the heart contracts,
under fuch circumftances, the body is alive ; when not,
it is dead.   Life he therefore defines to be the faculty of
propelling the fluids through the circulatory fyftem. Ac-

(marginal notes)

Hunter.

Goodwyn.

cording to him, the external concomitant circumstances which operate upon the body in health are heat and refpiration, which excite the vital principle to action; and whenever the functions of an animal are fuddenly fufpended, and the body puts on the appearance of death, it is always in our power to determine whether it be really dead, by reftoring the temperature, and by inflating the lungs with proper air. He is of opinion, with fome others, that there are no means of determining the abfolute deprivation of the vital principle but by the prefence of putrefaction.

Currie, on appreciating the powers of life, affirms, that Currie. if a definition of it were required, it might be moft clearly eftablifhed on that capacity by which the animal preferves it's proper heat under the various degrees of temperature of the medium in which it exifts. That the more perfect animals poffefs this power in a fuperior degree: and this is neceffary from the exercife of their vital functions. That the inferior animals have it in a lower degree, and vegetables lower ftill; which is according to their limited powers and humbler organization. And as the capacity of preferving nearly an uniform temperature in all varieties of climate and feafon is a criterion of life in the more powerful animals, it is probable that a few degrees of increafe or diminution of the heat of the fyftem produce difeafes and death. Metzler fuppofes carbonic acid gas to afford the principle of life. De la Metherie looks upon the principle De la Me-of life to be the aura animalis, fomewhat analogous to therie. the aura feminalis; and Girtanner affirms irritability to be the principle of life. Somewhat before the time when Goodwyn publifhed his " Connection of Life with Refpiration," a revolution had taken place in chemiftry, and the attention of philofophers became more particularly directed to inveftigate the chemical proceffes that were fuppofed to take place in the animal economy, and by which the principle of life came in for it's fhare. This change

in the fyftem arofe from the difcovery of oxygen, which was found to be that principle which fome of the ancients had imagined to exift in the atmofphere—a certain fomething which they faw was neceffary to life. This oxygen is the pneuma that Ariftotle fays unites with the blood; and Chryfippus von Soli, who gave to the pneuma the moft extenfive range, exprefsly declares that it is what generates life; whilft Praxagoras the phyfician fays that the foul is ftrengthened by fpirituous air.

This theory of Chryfippus and Praxagoras had it's difciples in the middle ages, and in latter times it received great influence from the difcovery of the circulation of the blood. For this difcovery we are indebted to Michael Servetus or Andrew Cefalpinus, each having mentioned that circumftance before Harvey. It now became clear where the blood met with the infpired air, and how it was then fent through the body. Servetus exprefsly fays that the blood paffes through the lungs, obtains there an addition of vital fpirit from the atmofpheric air, and returns

Bacon. impregnated with this from the lungs to the heart. Bacon added to the doctrine of the pneuma, and fays the vital fpirit is compofed of air and fire, which by their union produce a weak combuftion, or, as it may be called, the *phlogiftic* procefs of life (*incenfio fpirituum vitalium*). Hence, from the time of Praxagoras there appears to have been a fimilar idea of a *material principle* of life, although differently modified; and this appears to have been the opinion likewife of Harvey, Mayow, and Mund, and to have

Townfend. defcended to the prefent times. Thus Townfend affirms, the vital force of an organ appears to be in the exact proportion of the quantity of oxygenated blood that circu-

Thornton. lates through it; Thornton, that there is a chemical procefs going forward in the body by means of oxygen; and

Brandis. Brandis, Reil, and Gallini are of the fame opinion, but fay the vital power arifes from a conftant change of animal

matter, a phlogistic process, which is maintained and re-
newed by an union of the oxygen with the carbon. Ac-
cording to Hufeland, life is a chemico-animal flame, to Hufeland.
the production of which oxygen is absolutely necessary,
and the vital power is the most general and powerful of
all the powers of nature. He considers it as the cause of
organization, and as possessing the following properties.
1. It has a greater affinity to some organized bodies than
to others ; thus, the polypus may be cut in pieces without
being divested of it, and a decapitated tortoise or a frog
deprived of it's heart will live a long time after ; whilst to
the human body, or a quadruped, it would be instant death.
According to this physiologist, it appears to be a general
rule, that the stronger the affinity is between life and an
organized being, the more imperfect is the animal : hence
the zoophytes, whose whole organization consists in a
mouth, a stomach, and a gut, have a life exceedingly te-
nacious, and difficult to be destroyed. 2. It is in greater
quantity in some organized bodies than in others. Thus
an elephant lives a century, whilst the ephemeron only
exists a day ; and in general all cold-blooded animals
live longer than those with warm blood. 3. It frees
bodies from the chemical laws of inanimate matter, and
transfers the component parts of a body from the physi-
cal or chemical to the organic or living world. 4. It
prevents putrefaction, for no organized body can putrefy
unless deprived of life.

Humboldt is of opinion, that the degree of vitality de- Humboldt.
pends upon the reciprocal balance of the chemical affini-
ties of all the elementary parts of which an animal is
composed.

Davy considers life as a perpetual series of peculiar cor- Davy.
puscular changes, and the living body as the being in
which these changes take place. They are consequently
found to be continually varying : and since all organic sen-

fitive beings are unable to exift without light and oxygen,
he looks upon thefe two, under the name of phofoxygen,
as effential to exiftence.

Dr. Ferriar, in his obfervations concerning the vital
principle, thinks that fome direct arguments may be
brought againft the general fuppofition of an independent
living principle. Thefe arguments he divides into two
kinds, viz. refutations of the general proofs offered in
fupport of the vital principle ; and inftances of the direct
influence of the mind and brain over what is termed the
independent living principle. The great proofs for the
fupport of a vital principle are, the contraction of mufcles
feparated from the body on the application of ftimulants ;
the performance of the vital and involuntary motions with-
out any exertion or even confcioufnefs of the mind, and
the birth of full-grown fœtufes deftitute of a brain.   In
all thefe cafes, fomething is alleged to operate, indepen-
dently of the mind, in producing mufcular motion.

Dr. Ferriar, in anfwer to the firft argument drawn from
the contraction of feparated mufcles, affirms, it may be
faid,   1. That the power of contraction in a feparated
mufcle is loft before putrefaction takes place, i. e. before
the deftruction of it's texture ; but if it's vitality depended
on it's texture this ought not to happen.   2. The power
of contraction in a feparated mufcle is ftrongeft upon it's
firft feparation, and becomes weaker by degrees : there-
fore the contracting power appears to have been derived
from fome fource from which it is detached by the exci-
fion of the part.   3. Irritation of the medulla oblongata,
or of the nerves fupplying particular mufcles, occafions
ftronger contractions than irritation of the mufcles
themfelves ; and Dr. Whytt furnifhes an experiment on a
frog, directly proving that the action of feparated mufcles
depends upon the nervous energy.   4. Dr. Haller himfelf
is obliged to make a conceffion on this fubject fufficient to

deftroy his favourite hypothefis of the vis infita. 5. When a paralytic limb is convulfed by the electric fhock, the motion never takes place without the patient's confciouf-nefs. In this cafe there is no diftinction between the vi-tal principle and that exertion which in voluntary motion is always attributed to the mind.

In anfwer to the fecond argument in favour of a vital principle, drawn from the performance of the vital and other involuntary motions, Dr. Ferriar contents himfelf with only obferving, that allowing the organs of thofe motions to be fupplied with nervous energy, their mo-tions may be very well accounted for by the ftimulus of their contained fluids.

The force of the third argument, drawn from the want of a brain in full-grown fœtufes, is taken off by Dr. Whytt, who remarks, that as the heart is fometimes wanting in full-grown fetufes, the argument would equally prove that the heart is not neceffary for the con-tinuance of circulation, as that the brain is not neceffary to the fupport of the fyftem. Accordingly, fetufes born without a brain do not in general furvive birth.

Befides the general fuppofition of an independent living principle, an inference has been drawn from facts, of a nervous energy independent of the brain. By this term is meant, that condition derived from the brain to dif-ferent parts of the body, by means of which they become capable of motion. To fhow by direct proof that there is no independent vital principle, Dr. Ferriar obferves, 1. That it is juftly urged by Dr. Monro againft the doc-trine of the vis infita, that there is too much defign in the actions of different mufcles, affected by different ftimuli, to be the effect of mere mechanifm. Thus, when the hand or foot is burnt, or otherwife fuddenly injured, the mufcles on the part immediately ftimulated are not thrown into action, nor the mufcles on the fide irritated, but their

antagonifts contract immediately and ftrongly. Now, if
the inftantaneous action be in this cafe chiefly produced
by an effort of the mind, the fuppofition of a diftinct
vital principle is fuperfluous : if it be faid to be produced
by a living power independent of the mind, then there
muft be a rational power in the body, independent of the
mind; which is abfurd. 2. The ftate of the vital and
involuntary motions is confiderably affected by the ftate
of the mind, which equally difproves the exiftence of a
feparate vital principle, and proves the dependence of the
nervous energy upon the brain. 3. Madnefs, it is well
known, is frequently produced by caufes purely mental,
and in perfons apparently in good health ; and as the pa-
tient's fenfibility to every powerful ftimuli is much dimi-
nifhed in maniacal cafes, they afford another proof of the
fubordination of the nervous energy. 4. It has been ob-
ferved, that in paralytic cafes motion is frequently de-
ftroyed, while fenfe remains. As the caufe of palfy al-
moft always refides in the brain; this fact appears equally
inexplicable on the opinion of a diftinct living principle,
or of a nervous energy independent of the brain. 5. When
nerves are regenerated after being cut through, fenfation
and voluntary motion are not always reftored to the parts
beneath the divifion : the reftoration was never made in
Dr. Monro's experiments. But on the fuppofition of a
diftinct nervous power, the nerve, after it's reunion,
ought to refume all it's offices. 6. Dr. Whytt afferts,
that when the fpinal marrow of a frog is deftroyed, after
decollation, no contraction can be excited in the limbs by
cutting or tearing the mufcles. Such are the facts and
arguments which Dr. Ferriar brings againft the opinion
of a diftinct living principle; and he thinks that their
inveftigation appears to lead us back to the brain as the
fource of fenfibility and irritability.

Dr. Rufh.   The laft opinion which has been given of the principle

of life is that of Dr. Rufh. He includes in animal life
three properties, as applied to the human body; viz. *mo-*
tion, *fenfation*, and *thought*, and thefe, when united, com-
pofe perfect life. It may exift without thought or fenfa-
tion, but neither fenfation nor thought can exift without
motion. He affirms, that the loweft degree of life exifts
in the abfence even of motion. He firft confiders ani-
mal life as it appears in the waking and fleeping ftates in
a healthy adult, and afterwards inquires into the modifi-
cation of it's caufes, in the foetal infant, youthful and mid-
dle ftates of life, in certain difeafes, in different ftates of
fociety and in different animals, and lays down the fol-
lowing propofitions :

1. Every part of the human body, the nails and hair
excepted, is endued with fenfibility or excitability, or
with both.

2. The whole body is fo formed and connected, that
impreffions made in the healthy ftate upon one part ex-
cite motion or fenfation, or both, in every other part
of the body.

3. Life is the *effect* of certain ftimuli acting upon the
fenfibility and excitability, which are extended in different
degrees to every external and internal part of the body ;
and thefe ftimuli are as neceffary to it's exiftence as air
is to flame.

That animal life is a forced ftate was firft delivered by
Dr. Cullen, although he afterwards retracted it. He af-
firmed that the human body was not an automaton or
felf-moving machine, but kept alive, and in motion, by
the conftant action of ftimuli upon it. Dr. Brown en-
larged upon this, and formed a beautiful theory of excita-
bility and excitement : and Dr. Rufh endeavours to efta-
blifh this difcovery of life being a forced ftate; and he
continues to obferve, that the action of the brain, the dia-
ftole and fyftole of the heart, the pulfation of the arteries,

the contraction of the mufcles, the periftaltic motion of
the bowels, the abforbing power of the lymphatics, fecre-
tion, excretion, hearing, feeing, fmelling, tafte, and the
fenfe of touch, even *thought* itfelf, are all the effects of
ftimuli acting upon the organs of fenfe and motion.
Thefe have been divided into external and internal.

1. The external are light, found,·odours, air, heat, ex-
ercife, and the pleafures of the fenfes.

2. The internal ftimuli are food, drinks, chyle, blood,
tenfion of the glands which contain fecreted liquors, and
the exercife of the faculties of the mind.

Life therefore (according to the hypothefis of Rufh),
even thought itfelf, is merely a quality refiding in the com-
ponent parts of a material fyftem, dependent upon a pe-
culiar organization, by which it is enabled to act, or in
fome way to move, on being ftimulated or excited.
Hence life can never be inherent in a fimple uncom-
pounded fubftance, nor in a particle of animal matter ;
and if the ftimulus be withheld from a living fyftem be-
yond a given time, all motion, fenfation, and thought,
muft neceffarily be extinguifhed.

He then inquires into the ftate of animal life in fleep,
in the fœtus, in infants, in youth and middle life, in
old age, in perfons who are blind, deaf and dumb, in
idiots, in thofe under the effects of long fafting, and in
thofe fuppofed to be dead, from drowning, freezing, and
other caufes. He afterwards takes a view of the ftate of
animal life among the different inhabitants of the globe,
as varied by civilization, diet, fituation, and climate. He
accounts for the influence of certain mental ftimuli, which
act nearly alike upon the individuals of all nations ; of the
caufes of life in all the different claffes of animals ; of the
caufes of life in vegetables ; of the caufes of death ; and
laftly, he draws his conclufions from the doctrine of ani-
mal life being the effect of impreffions upon the body.

Irritability.—Whatever motion there is in the animal body, it is all brought about by the mufcular fibre; and fince the connection of this fibre with oxygen is neceffary, in order that it fhall preferve it's irritable or contracting power, phyfiologifts have endeavoured to inveftigate what may be the nature and origin of irritability itfelf.

Gliffon is faid to be the firft difcoverer of the irritable principle in the folid fibre, and this was afterwards enlarged upon by Haller, who found by a variety of experiments that the irritability of mufcles remains a long time after their connection with the brain is deftroyed. He gave it the name of vis infita. Fothergill, in his Hints on Animation, publifhed in 1783, confiders oxygen as the proximate caufe of irritability; and Girtanner looks upon himfelf to be the difcoverer of the fame principle in the fluids of the body; and it is to this celebrated phyfiologift, and to Humboldt, that we are indebted for the moft curious obfervations on this principle.

According to Girtanner, who has made a number of experiments on the fubject, irritability is the principle of life in organized nature, and oxygen is the principle of irritability. His opinion is, that the irritable fibre, improperly called the mufcular fibre, is univerfally expanded throughout all organized nature. It is on this that organic motion, fenfation, and even life depends. He affirms that this irritable fibre is the fame in all parts, and fubject to the fame laws; that the fluids of animals are endued with irritability as well as the folids, their irritability confifting in their coagulability, which is fubject to the fame laws as that of the fibre; that the degree of irritability of the folids and fluids is continually changing, and is different, according to the age and regimen of the fame animal, according to the fex, organization, and fize of the individual; that the ftate of health, or the tone of the fibre, confifts in a certain quantity of the irritable

principle neceffary to it's prefervation. To maintain this
ftate, it is neceffary the action of the ftimulus be fuffi-
ciently ftrong to deprive the fibre of the furplus of the
irritable principle which the lungs and the circulation of
the fluids continually furnifh. When the irritability is
totally deftroyed, the fibre is in a ftate of gangrene ; it
changes it's colour, becomes livid or black, and is then
fubject to the laws of unorganized matter. That the
irritable fibre, from the firft moment of it's exiftence to
that of it's diffolution, being conftantly furrounded by bo-
dies that act on it by ftimulating it, and upon which it re-
acts by it's contraction, it follows, that during life the
irritable fibre is in a continual action ; that life confifts in
action, and is not a paffive ftate, as fome authors have ad-
vanced. According to the experiments of this phyfician,
poifons act on the blood, as was before obferved by Fon-
tana, by depriving it of the principle of irritability, or of
it's oxygen.

He then attempts to prove that it is to the oxygen, dif-
tributed to all parts of the fyftem by means of the circu-
lation of the blood, that the irritability and the life of or-
ganized bodies are owing. The proofs of which are,

1. The irritability of organized bodies is always in a
direct ratio to the quantity of oxygen they contain.

2. Every thing that augments the quantity of oxygen in
organized bodies augments at the fame time their irritability.

3. Every thing that diminifhes the quantity of oxygen
diminifhes likewife their irritability.

He diftinguifhes the organized fibre by three different
ftates :

1. A ftate of health, or the *tone* of the fibre, in which
the oxygen exifts in it's proper quantity.

2. A ftate of *accumulation*, in which the fibre is fur-
charged with the oxygen or irritable principle.

3. A ftate of *exhauftion*, in which the fibre is more or
lefs deprived of it.

He likewise arranges all substances, that are capable of coming into contact with the irritable fibre, into three classes.

The first comprehends those substances that have the same degree of affinity for the irritable principle or oxygen, as the organized fibre itself; hence the substances produce no effect upon it.

The second comprehends those substances that have a less degree of affinity for oxygen than the organized fibre has: hence these, when they come into contact with it, surcharge it with oxygen, and produce a state of *accumulation*. They are called negative stimuli.

The third comprehends substances for which oxygen has a greater affinity than it has for the organized fibre. These therefore deprive the fibre of it's oxygen, and produce a state of *exhaustion*. They are called positive stimuli.

It is a fact well known, that the affinity of different substances differs considerably, according to the degree of temperature. The same difference, according to this physician, takes place with the organized fibre; hence, in speaking of the affinities of the irritable fibre in general, he means the temperature to be that of the blood in warm-blooded animals. Having made this observation, his arrangement of different substances is as follows:

In the first class he arranges all organized or living substances, which produce no effect upon the irritable fibre as long as their degree of temperature is the same as that of the fibre with which they come into contact.

In the second class (negative stimuli) he arranges some of the most fatal poisons. And it is on this account that the oxygenated muriatic acid is so deadly a poison to all organized bodies. It destroys them by the surcharge of irritability, or by superoxygenating them; and the consequence is, it is changed into common muriatic acid. Arsenic in it's metallic state has no effect; but the white oxyd

of this metal is one of the moſt excruciating and terrible
poiſons.   The oxygenated metallic ſalts, as corroſive ſub-
limate, or oxygenated muriat of mercury and butter of an-
timony, produce the ſame effects.   Alſo the oxyds of ſil-
ver and mercury produce more or leſs effects on the orga-
nized fibre, according to the quantity of oxygen they
contain.   The black oxyd of mercury, or Æthiops mi-
neral, produces little or no action ; whilſt the red oxyd of
the ſame metal produces the moſt terrible effects, and de-
ſtroys organized bodies in a very ſhort time.   The action
of the ſulphats of tin and lead, and the acetates of lead
and copper, is the ſame on the organized fibre.

He aſſerts that the animal as well as the vegetable or-
ganized fibre decompoſes the water with which it comes
into contact ; that the greateſt part of the water we drink
is decompoſed, then recompoſed ; that it is another method
which nature makes uſe of to furniſh organized bodies
with the oxygen neceſſary to preſerve their life and irrita-
bility.   Hunger he looks upon as the conſequence of ac-
cumulated irritability in the ſyſtem ; and for a ſubſtance to
be nouriſhing, it is neceſſary for it to be a poſitive ſtimulus,
i. e. it muſt have a great affinity for the oxygen with
which the ſyſtem is overloaded, by which it gives tone to
the fibre, and ſtops the diſagreeable ſenſation of hunger.
Different ſubſtances, therefore, are only nouriſhing in
proportion to their affinity for oxygen.   It is on this ac-
count that living animal ſubſtances, as oyſters, afford little
or no nouriſhment, becauſe, being already ſaturated with
oxygen, they cannot combine with it ; and hence the well-
known obſervation, that oyſters increaſe the appetite.
Likewiſe animal jellies, fruits and vegetables, in general,
nouriſh very little, or not at all.   The fleſh of newly-
killed animals is not ſo nouriſhing as that kept for ſome
time, and when raw is leſs ſo than roaſted.   From this
ariſes all the art of the cook, which only conſiſts in de-

3

priving the flesh of it's oxygen by different stimulating substances, such as heat, oils, sugar, alcohol, and other substances that have a great affinity to oxygen, and are very nourishing. In the East-Indies, millions nourish themselves by eating small quantities of opium when their crops of rice fail.

Thirst is a state of the system opposite to that of hunger; it is a sensation that indicates an exhaustion or want of oxygen. Water therefore, on being decomposed, as it comes into contact with the fibre, gives up it's oxygen to stop this disagreeable sensation. The same happens with vegetable acids, which are always decomposed in the stomachs of animals. If these acids are the best remedies against the effects of narcotic poisons, it is owing to their giving up the oxygen, on decomposition, to the fibre which these poisons have deprived of it. Hence vinegar cures the effects of opium and drunkenness, which is likewise effected by a large quantity of water. The freshness of the air after rain arises from the aqueous vapours coming into contact with our bodies, and restoring to them their lost oxygen. That singular insect the rotifer may be revived, after having been perfectly dried, by moistening it with water, which, on being decomposed, restores to it it's oxygen, and consequently it's irritability, of which the stimulus of heat had deprived it.

In the third class (positive stimuli) he arranges alcohol, sulphuric æther, opium, and other narcotics; oil of laurel, and oils in general; fat, sugar, &c. All the substances are combustible; i. e. they have a great affinity to oxygen; and it is by the same property they deprive the organized fibre of it's irritability, by uniting with the oxygen they contain. Amongst the positive stimuli that produce the most terrible effects are those of the putrid fever or plague, and of mephitic gas, which exhales from putrid animal

subftances where the common air is not able to penetrate, as in tombs. The affinity of mephitic gas for oxygen is fo great, that as foon as it comes into contact with the organized fibre it deprives it of all it's oxygen, and produces death, which is fometimes immediately. The beft way therefore to prevent the effects of this gas, is to detonate nitre on burning coals. The oxygen of the nitre combines with the gas, and renders it inert ; and hence the ufe of refpiring oxygen gas by thofe who are fuffocated by it, and the frefhnefs, as they exprefs, which it affords.

Humboldt.

Humboldt, who has written an ingenious treatife on the nature and properties of the Galvanic fluid, looks upon irritability to be the common foundation of all vital action ; and that it depends upon the property of the elementary parts of the mufcular fibre to change their relative fituation on the approach of a ftronger or weaker ftimulus, whilft in the fenfible fibre of the nerve a fluid is accumulated called the Galvanic fluid ; and he likewife afferts, that by means of this Galvanic fluid the ftate of the irritable capacity of a nerve or mufcle may be afcertained, for which experiment a metallic ftimulus, compofed of zinc and filver, is neceffary. According to this chemical phyfiologift, many of the opinions of Girtanner on the fubject of irritability are erroneous ; for, from various experiments, not only the irritability of the mufcular fibre is to be increafed by fubftances that contain no oxygen, but he found that a fluid containing no oxygen increafes the irritability of the fibre more than any other known irritable means. Thus, if two organs of equal irritability be dipped in an alkaline folution, and in oxydated muriatic acid, the firft will become irritated to powerful motion, whilft the other remains motionlefs ; but according to the theory of oxygen, as a material principle of irritability, the contrary might be expected. Similar appearances take

place when alcohol, mufk, camphor, tartar emetic, and muriated barytes, are ufed; fubftances fuppofed to contain little or no oxygen.

With refpect to bodies that increafe or diminifh irritability, he found,

1ft. That all bodies containing oxygen increafed or *augmented* the irritability of the nerves, fuch as the oxygenated muriatic acid, oxyd of arfenic, &c.

2d. That all bodies which abforb oxygen diminifh or *leffen* this irritability; fuch as the fulphuret of potafh, folution of potafh, nitrous gas, &c.

With refpect to the *firft*, if a large nerve be laid bare, as the crural, and if it be touched with fubftances containing oxygen, as the acids, it fhows an irritability. The fame takes place with very irritable mufcles; as the heart of a frog, when it's motion begins to diminifh, by being plunged into an acid liquor, fuch as the oxygenated muriatic acid, has it's irritability reftored to it.

With refpect to the *fecond*. If this heart, however, remains too long in the acid, it's irritability is too much increafed, by receiving too great a quantity of oxygen, and the motions ceafe. To make them therefore reappear, fubftances muft be employed that can abforb this excefs of oxygen, fuch as the fulphurets of potafh, alkalis, &c. Thus, by moiftening the heart by the fulphuret of potafh, it's motions recommence. But the abforption of oxygen foon takes away all irritability: hence the motions ceafe again; and, to make them reappear, the oxygen muft be rendered to it again, by dipping it in the oxygenated muriatic acid.

He found that heat, alcohol, &c. equally reanimate the actions of the heart; that the arterial blood produces the fame effect, from it's containing oxygen, but not the venous blood. If the nerve of a part be tied, it lofes it's irritability; and the fame happens if the artery be tied,

which carries the blood to it, as Haller has proved. The
explanation this chemical phyfiologift gives of thefe facts
is the following. He lays down three principles as ne-
ceffary to excite the irritability.

1. *Oxygen*, which forms combinations with different
acidifiable bafes.

2. The *acidifiable bafes* of the fibre with which the
oxygen may combine. Thefe acidifiable bafes are, *carbon*,
with which it forms carbonic acid, or oxyd of carbon ;
hydrogen, with which it forms water, or oxyd of hydro-
gen ; *azot*, with which it forms oxyd of azot ; *phofphorus*,
with which it forms oxyd of phophorus.

3. The *Galvanic fluid*.

Thefe combinations, however, of oxygen with the
acidifiable bafes of the fibre cannot take place alone, the
fame as azot and oxygen mixed together do not produce
nitric acid ; but if the electric fpark is made to pafs
through this mixture, the azot and oxygen combine, and
the product is the nitric acid.

The Galvanic fluid produces, according to Humboldt,
the fame effect in the animal economy as the electric
fluid in the mixture of azot and oxygen. It is this Gal-
vanic fluid that, being conveyed by the nerves, brings
about the combinations of the oxygen with the different
acidifiable bafes of the fibre ; but when the nerve of a
part is tied, it prevents the fluid from paffing, which ex-
plains the reafon of the irritability being deftroyed.

The oxygen neceffary for thefe unions is carried by the
arterial blood in the courfe of circulation ; and the acidi-
fiable bafes which are to unite with it are found to be
already prefent in the fibre.

He found that every thing that augments too much the
quantity of the acidifiable bafes diminifhes the irritability,
and that every thing that increafes too much the quantity
of oxygen likewife diminifhes it ; and he thinks it very

probable that the fame takes place with refpect to the proportion of the Galvanic fluid.

It is therefore only in a juft equilibrium of thefe principles that the neceffary irritability of the parts confifts; and the manner of it's operation this phyfiologift thinks may be conceived in the following way:

Suppofe a fibre to be compofed of the following particles *o o o o o*, which are acidifiable bafes, azot, hydrogen, carbon, phofphorus; the arterial blood then carries the oxygen to them, and the Galvanic fluid, conveyed by the nerves, making a difcharge into the mufcles, the acidifiable bafes combine by this means, and they approach each other from their affinity becoming ftronger, and the fibre is then fhortened and contracted. In order to conceive the manner of the difcharge in the internal part of the body, it is neceffary to call to mind the manner of it's action externally.

For inftance, let the nerve be *a p m*, which is diftributed in the mufcle *o o*. The portion *m* of the nerve which is diftributed in the mufcle *o o* communicates to it a portion of it's Galvanic fluid; whilft the portion *p a* fuppofed to be detached from the mufcle, and furrounded by air, which is not a conductor of this fluid, preferves it wholly. This portion *p a* contains, then, more Galvanic fluid than the mufcle *o*. If, therefore, thefe two portions be directly put into contact, there will immediately be a difcharge of the Galvanic fluid, which will pafs from the nerve *a* into the mufcle *o*.

The irritability may be likewife excited by eftablifhing a communication between the nerve and the mufcles by means of animal fubftances, as conductors, fuch as pieces of flefh or of nerve; alfo by placing a homogeneous metal, moiftened on one fide with an evaporable fluid, as water, between them.

It is the fame with refpect to mufcular motion internally.

In a ſtate of repoſe, the nerve being inſerted in the muſ-
cles, the gaſtric fluid is put into an equilibrium in the or-
gans that touch each other. The ſpontaneous motion is
made by a ſurcharge of Galvanic fluid into the nerve. It
appears that, the inſtant we wiſh to make a motion, the
Galvanic fluid produced in the brain is carried in maſs
towards the part that ought to move, and ſurcharges the
nervous fibres. A diſcharge from the nerve is then made
into the muſcles. The particles of theſe laſt, animated by
increaſed affinities, approach each other, and it is this that
conſtitutes the phænomena of contraction. The acidifi-
able elements, azot, hydrogen, carbon, and phoſphorus, of
which the muſcular fibre is compoſed, combine amongſt
themſelves, and with the oxygen of the arterial blood. Muſ-
cular motion, therefore, is productive of an aqueous fluid,
as ſweat, carbonic acid, nitric acid, oxyd of phoſphorus,
ammonia, ſoda. The Galvanic fluid being decompoſed,
or rendered latent by contraction, and the chemical phæ-
nomena that accompany it, the particles of the muſcle
reenter the ſphere of their primitive attraction.

If the Galvanic fluid is carried away without the direc-
tion of the will (as is the caſe in diſeaſes), and in too
great quantity to one part, it gives riſe to ſpaſm and con-
vulſion, which laſt has been put a ſtop to by the touch of
metallic ſubſtances, which, being conductors of the Galva-
nic fluid, diſſipate it. It is upon this principle, according
to Humboldt, that Perkiniſm is founded, or the method
of curing diſeaſes by metallic points. Dr. Rafn of Co-
penhagen has publiſhed a book on this ſubject. The
manner of uſing them is to preſent them to the diſeaſed
part, and relief is ſaid to have been the conſequence. The
metallic points are commonly made of ſteel or ſilver, and
are uſed in different manners. If by theſe the patient has
in reality been relieved, it may be ſuppoſed to have ariſen
from diminiſhing or increaſing the Galvanic fluid in the

part relieved; and it is perhaps on the fame principles that magnetic plates have produced the good effects on applying them in the fame manner to the difeafed part, if it be true that cures have been effected by them.

Mufcular motion, from what has been faid, always fuppofes an abundant emiffion of the Galvanic fluid, and the fame is the cafe with all the other functions. Thus digeftion only operates by the Galvanic fluid, which renders the gaftric powers active. Thought alfo equally requires the Galvanic fluid, which is conveyed to the place where it is to be put into execution: hence, in the time of digeftion, it is to be fuppofed that thought either cannot take place, or that it fhould turn the Galvanic fluid elfewhere, and the digeftion be difturbed. And as thought likewife requires a great deal of Galvanic fluid in the thinking organ, it is neceffary that all the other motions, except the vital, be fufpended, or *thought* cannot be made freely.

On this hypothefis, therefore, the different animal functions are a feries of continual combinations made in the body.

The chief principles of the animal fibre, according to the ingenious philofopher Davy, appear to be nitrogen, Davy. hydrogen, carbon. oxygen, and light. He thinks the immediate caufe of irritable action to be moft probably the combination of the oxygen with the hydrogen and carbon forming water and carbonic acid, and liberating the azot and electric fluid; fince it is certain that water and carbonic acid are liberated during mufcular action; and probably azot, and light in it's condenfed ftate electric fluid; as it is well known that the torpedo and fome other animals give out the electric fluid during animal action. He thinks that in man the quantity is probably too fmall, and too flowly liberated, to be afcertainable. He looks upon the laws of mind to be moft probably not different from the laws of corpufcular motion; that every change in

our fenfations muft be accompanied with fome corre-
fpondent change in the organic matter of the body; but
thefe changes an extenfive and philofophic chemiftry
muft enable us to find out; that, by the difcovery of them,
we fhould be informed of the laws of our exiftence, and
probably enabled in a great meafure to deftroy our pains
and increafe our pleafures. Thus would the fcience of
chemiftry become the moft fublime and important of all.

Tractatus de Naturâ Subftantiæ energeticâ, feu de Vitæ
Naturâ, à Francifco Gliffonid. London, 1672.—The
Connexion of Life with Refpiration, &c. by Edmund
Goodwyn, M. D. p. 99. London, 1788.—Mémoire fur
l'Irritabilité, confidérée comme Principe de Vie dans la
Nature organifée, par M. Girtanner.—Journ. de Phyf.
1790.—Verfuch über die Lebenfkraft, von J. D. Brandis.
Hanover, 1795.—De la Metherie, in his Journal de Phy-
fique, p. 32. tom. 48. Paris, 1799.—Hufeland die Kunft
des Menfchliche Leben zu verlangern. Jena, 1798.—Ver-
fuche, &c. nebft vermuthungen über den Chemifchen
Procefs des Lebens, &c. von F. Alex. von Humboldt.
2 vols. Berlin, 1799.—Obfervations concerning the Vital
Principle, by John Ferriar, M. D. Manchefter Memoirs,
vol. iii. p. 216.—Three Lectures upon Animal Life, by
Benjamin Rufh, M. D. Philadelphia, 1799.

Refpiration.   *Refpiration.*—The procefs which nature employs to
oxygenate the blood, by means of the lungs, is called re-
fpiration; a function not only enjoyed by the animal, but
alfo in fome degree by the vegetable creation; and fo ef-
fential is it to life, that wherever vital organization is
found to exift there is no exception to the general rule.

Compofed
of two acti-
ons, infpi-
ration and
expiration.
  This function is compofed of two actions; the dilatation
of the thorax, by which a quantity of air is received into
the lungs; and it's contraction, by which the air is expelled
from them: and thefe two actions take place alternately.
According to the prefent theory of refpiration, infpiration

is the means of communicating the oxygen of the air to the blood, which, in confequence, is changed from a dark to a fluid red colour, and there is an extrication of caloric producing animal heat. Expiration, on the contrary, is found to convey what might be hurtful, fuch as fixed air and aqueous vapour out of the lungs.

In all animated beings, the final intention of this func-tion is the fame; but on examining the parts in different claffes of animals, the organs by which refpiration is produced are exceedingly varied. On taking, however, a general view, perhaps the moft fimple divifion of the refpiratory organs will be the following.

1. Lungs, as in man; quadrupeds of the two orders; birds; and the cetaceous clafs.

2. Gills, as in fifhes.

3. Stigmata, or holes in different parts of the body, as in infects.

Of thefe three fpecies there are great varieties of form, but the office in which they are employed is the fame; thus the varieties of the firft and laft fpecies of refpiratory organs communicate the oxygen to the blood by the at-mofphere, whilft thofe of the fecond fpecies communicate it by water.

There are two obfervations which have been made upon the refpiratory organs of animals.

I. The quantity of blood is found to be in a given ratio to the perfection of their refpiration, whilft the difference of the circulatory organ or heart is always in a ratio to that obferved in the refpiratory organ; both of thefe func-tions undergoing, in fome meafure, a gradual degenera-tion in the different claffes of animals, and the animal heat keeps the fame ratio; hence a fcale may be formed of thefe gradations in the following manner.

1. Quadrupeds. 2. Cetacea. 3. Birds.	4. Ovip. Quad. 5. Serpents 6. Fishes.	7. Insects. 8. Worms.
Blood in large quantity, and hot.	Blood in small quantity, and nearly cold.	A white liquor instead of blood.
Two ventricles in the heart.	One ventricle.	Heart of different forms, or unknown.
Respire by lungs, and frequently.	Respire at long intervals; some by lungs, others by gills in their imperfect state, and others always by gills.	Respire by stigmata, or by unknown means.

1. Of quadrupeds, cetacea, and birds, the last have the most extensive lungs, and they are found to exceed the two other orders in possessing a higher temperature; but this perfection of their respiration, as it has been called, has it's disadvantages; and they are the first to feel the bad effects of noxious airs, which have been proved by experiment to be sooner fatal to them than to the others.

2. Oviparous quadrupeds, serpents, and fishes, have their blood still less warm, their lungs smaller; and whether gills or lungs, a smaller quantity of oxygen is of course communicated to their blood, which is less in quantity than in the before-mentioned orders. Of the oviparous, who can stop their respiration for forty or fifty minutes, and upon which animals experiments have been made, they are found to resist even carbonic acid gas for a great length of time, and do not die in less than fifty minutes; a small portion of blood only passes through their lungs, the rest being conveyed immediately from one ventricle to another. Fishes have likewise less blood in proportion to their bulk than quadrupeds, which agrees very well with their imperfect respiratory organs. In these, however, there is great variety. Thus the cartilaginous species of fishes that have their respiratory organs more extended than others have likewise a larger proportion of blood. The pike, also, the organs of which are more complete that those of the

carp, contains more blood, but cannot live fo long out of water; and the carp, refpiring in a more perfect manner than the eel, is likewife furnifhed with more blood.

3. With refpect to infects the difference is more ftriking; their heart is membranous, fcarcely fufceptible of motion, and inftead of lungs they have only veffels diftributed to different parts of the body. Their blood, if it can be fo called, has not that red colour which characterizes that fluid in other animals; but they are very tenacious of life, and are not eafily deftroyed on refpiring noxious airs. Thus, according to Young, animals of this order, as wafps, &c. when expofed to carbonic acid gas, although they become torpid at firft, foon recovered from their lethargy, and appeared to fuftain the effects of the air without any inconvenience.

II. The fecond obfervation which has been made refpecting the organs of refpiration is, that the more perfect refpiration is, the more are it's organs concealed. Thus birds, whofe refpiration is fo perfect, at leaft according to Brouffonet, have the air conducted even into the cavities of the greater part of their bones; and confequently their organs are more internally fituate than thofe of quadrupeds, in which the lungs only, defended by the thorax, are more concealed than thofe of the oviparous tribes, the refpiratory organs of which are placed externally during the firft period of their life, and internally the remaining part, when their metamorphofis obliges them to breathe the atmofpheric air. The organs of fifhes, or their gills, are nearly uncovered, and may be feen without deftroying or taking away any part; but as they breathe in a more perfect manner than the mollufca and aquatic fhell-fifh, their organs are even more concealed; in which laft they are moft commonly fituate externally, and are perfectly expofed. It is in thefe that this function appears to be nearly effaced; and, in order to dif-

cover it, we can, in general, be guided only by ana-
logy. In the vegetable tribes the leaves are their refpira-
tory organs, and are only of ufe during a part of the
year : in winter they are deprived of them. The abfolute
neceffity of breathing muft certainly have been known to
the earlieft ages of antiquity : it's great importance feems
even to have been acknowledged by Mofes :—" And the
" Lord God formed man of the duft of the ground, *and*
" *breathed into his noftrils the breath of life, and man be-*
" *came a living foul.*" Gen. ii. 7.—But the difcovery of
it's ufe, and more particularly the procefs which is car-
ried on in the fyftem during refpiration, is, like moft
other difcoveries of the firft magnitude, only of modern
date ; nor could the ancients have been capable of form-
ing any tolerably precife idea of the fubject, from their
ignorance of the nature of the atmofphere itfelf. We are
informed by Diodorus Siculus, it was an opinion amongft
the ancient Egyptians, that the atmofphere was incorrup-
tible ; that it was of fuch extent as to reach even unto
Heaven ; that it's moft important office was in concurring
towards the generation of all animals ; and it appears,
from the epithet of Glaucopis, which they gave to the
goddefs of the air, that they confidered the blue firma-
ment as peculiar to it's colour. This opinion of air being
the principle of all bodies was fupported by many Greek
philofophers, fuch as Anaximenes, Diogenes of Apol-
lonia, and Archelaus the mafter of Socrates. From the
nature of air being fo little underftood, it cannot be fup-
pofed that their notion of refpiration could be very exact ;
and we are informed that Empedocles was of opinion it
was brought about principally by the nofe, and that it was
determined by the void, which the motion of the blood
alternately operated in a part of the veins.

Notwithftanding the imperfect knowledge of the an-
cients refpecting this function, they knew very well how

indifpenfable the neceffity of air was to the fupport of life,
that neither animal nor plant could live without it. They
knew that when animals had remained a certain time in
a given quantity of atmofpherical air, they began to lan-
guifh, and become to all appearance fleepy; that this fleep
was at firft peaceable, but was foon followed by great
agitation; that refpiration then became difficult and pre-
cipitate, and that death fucceeded in convulfions. Thefe Ariftotle.
facts were well known to Ariftotle, Eriftratus, and Are-
tæus. Hippocrates reckoned air a fpecies of aliment that Hippocra-
was neceffary to the animal fyftem. The opinion, how- tes.
ever, which appears to have prevailed the longeft and moft
univerfally amongft the ancients, was, that refpiration is
chiefly intended to temper the blood, and carry off the
fuliginous vapours with which it is loaded by the vital fire
conftantly kept up in the heart. This hypothefis was
ftrongly fupported by Galen. Four ages after Ariftotle Galen.
we find the knowledge of this fubject fcarcely any fur-
ther advanced. Pliny calls the air the vital fpirit, and Pliny.
Cicero affirms that the heart imbibes a fpirit from the air. Cicero.
Among the moderns, Defcartes revived the hypothefis Defcartes.
which Galen had fo well fupported, and maintained the
fame vital fire in the heart, fuppofing that air was ne-
ceffary to cool and condenfe the blood. Borelli reckons Borelli.
the great ufe of refpiration to confift in the admiffion and
mixture of air with the blood, in order to inform thofe
elaftic globules of which it is compofed, to give it it's florid
rednefs, and to prepare it for many purpofes of the animal
œconomy. Bathier was of opinion that, during refpira- Bathier.
tion, the more fubtile and elaftic particles of the air were
imbibed, and the cruder part expelled through the pores
of the pulmonary arteries into the trachea. Van Hel- Van Hel-
mont afcribed the volatility of the fixed elements in the mont.
food to this air; and Stephenfon thought that the air
which had circulated in the blood, and which had heated

it too much, was exhaled by the lungs. Boyle and others thought that the air itself is not admitted to the blood, but that some active, spirituous, and ethereal particles were communicated to it ; that this vital spirit passes from the lungs to the heart and arteries, and at length becomes the animal spirits, which are, by this means, generated by the air. Those, on the contrary, who did not admit that the animal spirits are derived from the air, still say that some other *vital principle* comes from thence. This vital principle, imbibed from the air, Malpighi calls a saline vapour ; Lister, an inflammable sulfureous spirit ; Vieuffens, a volatile acid salt, which keeps up the fermentation of the blood ; and Bryan Robinson, that it is the aërial acid which preserves it from putrefaction, and gives strength to the animal fibres. Hence he supposes it is that we feel ourselves refreshed in cold air, as it abounds with a more acid quality. But of all the opinions that have been given respecting the function of respiration, the theory of Mayow is the most deserving of attention.

This celebrated philosopher lived about the middle of the 17th century. He was contemporary with Boyle, Lower, and Willis ; and so acute was his observation of natural phænomena, and so just his judgment on the causes which produced them, that, with respect to respiration, Dr. Beddoes has very properly observed he has, in some measure, anticipated the discoveries of the present day. His works give an account of the use of the air in combustion and respiration, or it's diminution and absorption by them. They assert, in a very clear and positive manner, the absorption of one part of the air by the blood, which he calls the vital part, as well as the warmth of this fluid produced by this absorption, or by the presence of air in the lungs. Mayow has likewise shown that the red colour of the blood, and the change of the venous into arterial blood, depend entirely on the contact of the atmo-

ſpheric air ; and had he known how to have extracted the
vital air of the atmoſphere from the ſubſtances that ab-
ſorbed it, had he but known it's properties when in it's
pure and iſolated ſtate, he would have eſtabliſhed all the
principles of the preſent theory of combuſtion, reſpira-
tion, and the formation of acids, general ideas of which
are to be found in his works.

It appears from theſe, that 120 years ago he had ima-
gined an apparatus by which he could determine that the
air was in part fixed, or diminiſhed, and abſorbed by com-
buſtion and reſpiration ; that theſe two phenomena acted
upon it in the ſame manner ; and that there was only one
part of the air, the moſt ſubtile and elaſtic, which may
be called vital, and that ſerved both for inflammation and
reſpiration. "What confirms our hypotheſis," ſays he,
"is, that the air, on coming from the lungs of animals,
"is found diminiſhed in it's elaſtic force on account of it's
"nitro-aerial principles being exhauſted by reſpiration :
"theſe experiments will prove the laſt aſſertion. Attach
"a wet bladder to the circular edge of the orifice of a
"veſſel, like a ſkin extended on a drum ; place a ſmall
"cupping-veſſel containing a mouſe upon this bladder,
"and load it with a weight to prevent the animal over-
"throwing it. A few inſtants afterward you will ſee the
"cup adhering ſtrongly to the bladder, and this puſhed
"into the veſſel as if the flame had been under it. This
"phenomenon will take place whilſt the animal ſtill
"breathes. If you attempt to take away the cup, you
"will raiſe at the ſame time the bladder, which ſtrongly
"adheres to it, and with it the veſſel it covers, unleſs it
"be too heavy : and, in effect, a mouſe put into a cup-
"ping-veſſel, and applied to the ſkin, is able to ſupply,
"to a certain point, the flame which it is cuſtomary to
"produce in it. The reſult certainly is, that the elaſ-

" ticity of the air contained in the veffel has been dimi-
" nifhed by the refpiration of the animal, in fuch a man-
" ner as no longer to fuftain the preffure of the atmo-
" fphere.

" To give a better conception of this refult, we fhall
" add another experiment analogous to it, which will
" ferve to determine what fraction, what part of the air,
" deprived of it's vital particles by refpiration, is diminifh-
" ed in it's volume. An animal is to be placed in an in-
" verted glafs, or fufpended in a prifon or grate at the
" top of a glafs cucurbit : the orifice of the cucurbit is
" then placed in a jar, and plunged into water, in fuch a
" manner as this may rife to the fame height as externally,
" which may be attained by the affiftance of a crooked
" fyphon already defcribed : the exterior water is to be
" fomewhat voided, fo that the water in the cucurbit may
" be better feen ; the height of which is to be marked by
" a paper glued upon the outfide of the veffel. The
" water foon rifes in the cucurbit, and continues to rife
" by degrees, although the heat produced by the animal,
" and the exhalations produced from it's body, would feem
" to produce a contrary effect. In order to terminate the
" contraction the air in the veffel undergoes before it is
" become incapable of fupporting the life of the animal,
" the following method may be employed : the fpace oc-
" cupied by the air is to be meafured at the moment the
" moufe is introduced, and afterward that to which it has
" been reduced after the fuffocation of the animal, and
" the afcent of the water, which is done by the volume
" of water employed to fill thefe fpaces : leaving the ap-
" paratus in the fame ftate, the height of the firft fpace
" above the fecond is then to be calculated, and the dif-
" ference is the meafure of the volume and of the elafticity
" diminifhed by the refpiration of the animal. I am

" affured by different experiments made with different
" animals, that the air lofes about one fourteenth of it's
" volume by refpiration.

" It is then very evident, that animals in refpiring abforb
" certain vital and elaftic particles from the air. There is
" no doubt but that there enters, by refpiration, fome-
" thing aerial into the blood of animals which is neceffary
" to life. It is not only for the attrition of the blood that
" the lungs and their functions are deftined, &c. nor is
" it certain whether this aerial principle is abforbed by
" the capillary tubes, or the extremities of the fanguineous
" veffels : but the air is not lefs deprived of it's elafticity
" by refpiration than by combuftion ; and there is reafon
" to believe that animals take particles of the fame fort
" as fire does from the air, as the following experiment
" proves.

" If an animal and a lamp be enclofed in a glafs veffel
" which has no communication with the external air,
" which is eafily done by inverting this veffel into water,
" the light will foon be extinguifhed, and the animal will
" not refift a long time this *cruel torch*, tædæ ferali.   I
" have found by obfervation, that an animal enclofed in the
" fame glafs with a lamp does not breathe longer than
" half the time it would have done if alone. It is not the
" fmoke which fuffocates it ; for fpirit of wine, that affords
" no fmoke, produces the fame effect : but the air, yield-
" ing it's nitro-aerial particles to the flame, can no longer
" furnifh the animal with them.   This has no occafion
" for fo many igneo-aerial particles as the lamp ; for the
" lungs, as it were, go in fearch of them to abforb them :
" as to the flame, it is neceffary for them to be near it,
" prefent themfelves, and be inceffantly renewed : hence
" the animal exifts fome time after the extinction of the
" lamp, and when the aerial particles are almoft entirely
" exhaufted.   It is on that account that the air in which

" the animal is fuffocated undergoes more than twice the
" diminution of that in which a candle is extinguifhed,
" as has been feen. I have tried in vain to light again, by
" the affiftance of a burning glafs, the combuftible matter
" contained under the fame veffel as the animal that had
" expired ; and although it is poffible that the foggy feafon
" of the winter may have produced fome incertitude in
" this experiment, it is not lefs probable that the air
" which is no longer proper to fupport the life of animals
" is no longer fo to fupport flame, fince more aërial par-
" ticles are neceffary for the inflammation of the lamp
" than for refpiration : it is however not to be concluded
" from hence that the mafs of blood is in a real combuf-
" tion."

He alfo obferves, that mice and birds placed towards
the fuperior part of the cucurbit died fooner than thofe
in the inferior part ; and that in the firft cafe the water
did not rife fo high. He obferves, that if two animals be
put at the fame time into the fame veffel, the one in the
top part and the other below, the firft foon dies, and the
other furvives it for fome time ; from which he concludes
that the air, deprived of it's nitro-aërial particles, is be-
come lighter, and that the part of it which ftill preferves
them occupies the inferior part of the veffel. He fays,
therefore, that an animal which begins to fuffer from
want of air raifes it's head towards the upper part of the
veffel ; but finding itfelf more affected in this place, it im-
mediately plunges it's head below again, and keeps it fixed
at the bottom. He applies the fame remark to a candle,
which, when carried to the top of the veffel, is extin-
guifhed much fooner than below, becaufe the air be-
comes incapable of fupporting the flame ; and fince it is
become at the fame time lighter than the atmofpherical
air, it is pufhed towards the top of the cucurbit, and not
permitted to depart ; which proves that the air is deprived

of certain folid and heavy particles by inflammation and refpiration, fince it acquires lightnefs on coming from the flame and the lungs.

He likewife obtained, without knowing it, nitrous air or gas (by the means of iron wire and the nitrous acid) ; and having obferved the diminution of air by this gas, he with reafon compares this effect to that produced by can-dles and refpiration, fifty years before Hales had obferved the fame, and a century previous to the difcovery of Prieftley refpecting nitrous air, and it's property of form-ing nitrous acid with the vital air of the atmofphere.   He is of opinion, that the nitro-aërial fpirit is condenfed in the fame manner by the blood as by the iron-wire in the nitrous acid (by which he procured the gas), *i. e.* by fer-mentation : hence it is to the fanguineous fermentation that he attributes the fame condenfation in refpiration.   He thinks that the fermentation of the blood is produced by fhe condenfation of the nitro-aërial fpirit, and this con-denfation by the fermentation of the blood ; for, the par-ticles of this fpirit once condenfed, he admits their intro-duction into the mafs of the blood ; and to thefe he at-tributes it's red colour, it's heat, and fluidity. It is on this account, he fays, that the blood is black in that part which does not touch the air, and very red in that part which is in contact with it ; that the venous blood is black, and the arterial of a fplendid red ; that violent exercife heats, by multiplying the infpirations; that a perfon becomes warmer by voluntarily increafing his refpiration ; that the fevers of confumptive people arife from the force with which the pus of the lungs attracts and abforbs the nitro-aërial fpirit, with which it produces a great fermen-tation ; that, venous and arterial blood being placed under the vacuum of Boyle, the firft only offers a few blebs, whilft the fecond is totally converted into foam.   He adds, that this nitro-aërial fpirit gives the red colour to

bodies in which it exifts, as to the fuming fpirit of nitre. He compares the heat produced by the condenfation of this fpirit in the lungs, with that produced by pyrites in effervefcence; and he attributes the vitriolization to the fame caufe.

Such are the principal facts which Mayow delivered to pofterity, at a time when the fubjects on which he treated were little underftood, and his experiments ftill lefs fo, by the age he lived in. No philofopher, at the end of the laft century, had given any theory of combuftion and refpiration, or any account of the analogy between thefe two natural phenomena; of the reciprocal influence between them and the air; and of the effects produced by this fluid compared with thofe of nitre on combuftible bodies, with fo much detail and fagacious ingenuity as this phyfician. His works form an epoch in the annals of refpiration. In giving Mayow all the merit due to him, it appears, however, that although he had determined with great precifion the ufe of the nitro-aërial fpirit of the atmofphere to be to warm the blood and give it it's brilliant red colour, he was ignorant whence thefe phenomena arofe, and how the air contributed to it: and although thefe nitro-aërial and igneo-aërial particles may be looked upon as the vital air or oxygen gas of the moderns, he knew nothing of it's properties, nor the change it underwent by the action of flame and refpiration. Thefe explanations were referved for Prieftley and Lavoifier.

Malpighi. Malpighi has been already mentioned. It was a received opinion, that one ufe of the lungs was to attenuate the blood; and, according to Malpighi, the different parts of the blood by this means become thoroughly mixed together; while others were of opinion, that the blood is condenfed in the lungs; and others, that the globules and all the finer humours receive their configuration

there. Some, without confidering the air as of any other ufe than to put the lungs in motion, thought that heat is produced in the lungs by the attrition of the blood in paffing through them. The red colour of the blood has been thought by fome to be caufed by this attrition in the lungs; but Lower refuted this notion, chiefly by ob- Lower. ferving that the attrition of the blood is greater in the mufcles, from which, however, it always returns black. Whytt thought there was fomething of a vital and ftimulating nature derived from the air into the blood. Sir Ifaac Newton imagined that the atmofpheric air might Newton. communicate an acid vapour to the blood in the lungs, which was neceffary to keep up the action of the heart. According to Boerhaave, air which has not been changed Boerhaave. is deadly; not on account of heat, rarefaction, or denfity, but from fome other *occult caufe.*

Dr. Hales, who, if we except Mayow, has thrown Hales. more light on the doctrine of air than any of his prede- ceffors, was equally ignorant of the ufe of it in refpira- tion, and feems to have adopted, at different times, dif- ferent ideas of it. It appears, from various paffages in his Statical Experiments, that he believed the red parti- cles acquire confiderable degrees of elaftic vibrations, if not an electrical virtue, in paffing through the lungs; " for (fays he), while by the extraordinary frictions they " undergo they are much heated and dilated, they are at the " fame time refrigerated and contracted by the frefh air " that is continually taken into the lungs; for the coats of " the veficles are fo extremely thin, that thofe two fluids are " fuppofed to be 1-1000th part of an inch within contact " of each other: fo that, like blended liquors, they muft " needs have a confiderable effect upon each other; the air " in cooling the blood, and the blood in warming the air." He is likewife of opinion, that the red colour of the glo- bules intimates their abounding with fulphur; that the

air is rendered alkaline by breathing ; and that fuffocation is owing to the collapfing of the minute veficles of the lungs, in confequence of the confined air being deprived of elafticity, and the contraction occafioned by the ftimulating fulphureous vapour. He fays the venous blood is not florid; which floridnefs in the arteries may be owing to the greater velocity with which it paffes through the lungs than other parts of the body; for blood agitated much in a clofed veffel was obferved to become very florid, even as much as arterial : but the great purpofe of the lungs is to refrigerate the blood.

Haller.   Haller, after giving the opinions of all that went before him, fays that the ufe of the lungs is partly inhaling and partly exhaling ; that the lungs *inhale* both water and air, but that in them the air lofes it's elaftic property, fo as to be eafily foluble in water or vapour ; and he thinks it. probable that the air ferves as a cement to bind the earthy parts together. He does not doubt but that various other matters, mifcible with water, are inhaled by the lungs; and he thinks it not improbable but that the air may carry fome electric virtue along with it. The principal *exhalation* of the lungs he thinks to be water, abounding with oily, volatile, and faline principles ; and thefe oily and fœtid vapours, he thinks, are the *fuligines* of Galen and the ancients.

Cigna.   Cigna, in a work *De Refpiratione*, takes it for granted that air which has been once refpired becomes unfit for further refpiration, becaufe it is loaded with noxious vapours, to be known by their fœtid fmell. He fays that air is diminifhed by refpiration ; and that air which has been breathed fuffocates by means of the irritation it occafions to the lungs, by which the bronchia, and the lungs themfelves, are contracted fo as to refift the entrance of the air ; and therefore that refpired air is noxious on the fame account as mephitic vapours, or thofe of burning fulphur :

that in frequently breathing the fame air it becomes fo loaded with thefe vapours as to excite a convulfion of the lungs, and thereby render them unfit for tranfmitting the blood. He fuppofes that air enters the pores of the blood, retaining it's elaftic power ; and that it continues at reft there, becaufe it's endeavour to efcape is counteracted by the equal preffure of the ambient medium. This air he-thinks is introduced by the chyle, and never by the way of the lungs, except when, by fome means or other, the equilibrium between the air in the blood and the external air is loft. If the external air be rarer than the internal, the air in the blood, expanding itfelf, will inflate the ani-mal, and have the fame effect as air introduced into the veins.

Upon the whole, he concludes that the principal ufe of air to the *blood* is to preferve the equilibrium with the ex-ternal air, and to prevent the veffels from being rendered unfit to tranfmit the blood, on account of the external preffure ; whereas, by means of the air they contain, the fluids move in their proper veffels as freely as in *vacuo*, and the membranes and vifcera alfo eafily flide over each other. With refpect to the ufe of the lungs, fince he imagined that air is not introduced into the blood by means of them, he thinks that becaufe fuch lungs as thofe of men are given to the warmer animals only, the chief ufe of refpiration is exhalation, and confequently the cooling of the blood.

On cafting the eye over the variety of opinions which for fo many centuries have taken place of each other re-fpecting the ufe of refpiration, it may appear fomewhat extraordinary that no one fhould have been fo fortunate, if we except Mayow, as to conjecture rightly ; but this furprife will be diminifhed on confidering, that, before any real light could be thrown on this obfcure fubject, it was ne-ceffary that the nature and component part of the atmo-

fphere we breathe fhould be inveftigated and made known.
Some chemical philofophers were engaged at the fame
time upon this interefting fubject, and their labours upon
the air and the different gafes have been crowned with
Difcovery
of oxygen
gas in the
atmofphere.
fuccefs. A pure aërial principle was found to exift in the
air much about the fame time by Dr. Prieftley, who called
it *dephlogifticated air* ; by Scheele, who named it *empyreal
air* ; and by Lavoifier, who gave it the name of *highly
refpirable* or *vital air* : and as it was afterward found by
the French chemifts to be the acidifying principle to the
bafis of acids, they call it *oxygen*, or, in it's combination
with caloric, *oxygen gas.* What therefore was only con-
jectured by Mayow to form a part of the atmofphere,
has been proved, beyond a doubt, to be the great agent in
the office of refpiration ; and as Boyle, Hales, Black, and
Prieftley, may be confidered as the firft who obferved
with accuracy that refpiration exercifes an evident action
on the atmofpheric air, that it diminifhes it's volume and
changes it's nature, and that, in a very fhort fpace of
time, the fluid made ufe of by this function lofes the
property of fupporting any longer the life of animals, a
clew was prefented to the chemical phyfiologift that
would lead him to account for all thefe phenomena.

Stahl's
phlogifton.
At the time of the difcovery of *oxygen*, as compofing a
part of the atmofphere, the prevalent doctrine was that of
Stahl. Beecher had imagined a fubftance to exift in in-
flammable bodies, which is the principle of inflammability,
and which is called *phlogifton*; and the genius of Stahl
had matured this into a theory, by which he accounted
for almoft every chemical phenomenon. The phlogiftic
fluid was either imbibed by or extricated from every thing.
The fectaries of Stahl applied this doctrine to explain the
effects of refpiration ; and they fuppofed that, during the
action of this function, a certain quantity of phlogifton
was exhaled from the blood as it paffed through the lungs,

which they faid phlogifticated the refpired air in the fame manner as they had admitted it's phlogiftication by com-buftion, the calcination of metals, and other proceffes which they called phlogiftic.

Amongft thefe philofophers was Dr. Prieftley. He informs us, that the property in the air which contributes to the fupport of life, and the reafon that air which has been much refpired will no longer ferve that purpofe, were not difcovered by any body ; and they might have continued to elude all *direct invefligation*, when they difcovered them-felves in the courfe of experiments upon airs which had at firft quite another object. According to this philofopher, in the experiments it clearly appears, that refpiration is a phlogiftic procefs, affecting air in the very fame manner as every other phlogiftic procefs, fuch as putrefaction, the effervefcence of iron filings and fulphur, or the calci-nation of metals, affects it, diminifhing the quantity of it in a certain proportion, leffening it's fpecific gravity, and rendering it unfit for refpiration or inflammation, but leaving it in a ftate capable of being reftored to a tolerable degree of purity by agitation in water, &c.   Having dif-covered this, he concluded that the ufe of the lungs is to carry off a putrid *effluvium*, or to difcharge that phlo-gifton which had been taken into the fyftem with the aliment, and was become, as it were, *effete*, the air that is refpired ferving as a *menftruum* for that purpofe.   He thinks the ufe of refpiration is confined to the blood, in confequence of it's coming fo nearly into contact with the air in the lungs, the blood appearing to be a fluid won-derfully formed to imbibe and part with that fluid called phlogifton, changing it's colour in confequence of being charged with it or freed from it, and affecting air in the very fame manner, both out of the body and in the lungs, even when various fubftances are interpofed which pre-vent it's coming into immediate contact with the air.

The black colour of blood Dr. Prieftley accounts for as arifing from imbibing phlogifton, as may be feen from his experiments quoted on the colour of blood; and when he had found how readily pieces of blood changed their colour according to the quality of the air to which they were expofed, the next thing was to examine the ftate of that air, to find what change had taken place in it; and as dephlogifticated air admits of a more fenfible change of quality than common air, he gave it the preference, putting a piece of craffamentum, about the fize of a walnut, into about five ounce meafures of this air.

This procefs he continued twenty-four hours, changing the blood ten or twelve times; after which he found the air fo far depraved, that whilft, at the beginning of the experiment, one meafure of it and two of nitrous air occupied the fpace of no more than half a meafure, the fame mixtures afterwards occupied the fpace of a meafure and a half. Now, fince air is univerfally depraved by phlogifton, and in this fenfe by nothing elfe, he thinks it is evident that this black blood muft have communicated phlogifton to the air, and of courfe it's change of colour from black to a florid red muft have arifen from this feparation of phlogifton.

The next day, when of courfe the blood was nearer to a ftate of putrefaction, in which every kind of fubftance will injure refpirable air, he put a quantity of red blood tinged in a few places with black, which he could not eafily feparate from it, to about the fame quantity of the fame dephlogifticated air, and fuffered it to ftand, without changing, for the fame fpace of time; when it was fo little injured that the meafures above mentioned occupied the fpace of only two thirds of a meafure.

That blood has a power of taking phlogifton from air, as well as imparting phlogifton to air, he fatisfied

himfelf by expofing blood of a very beautiful florid colour
to nitrous, inflammable, and phlogifticated airs. The
two firft kinds of air were confiderably diminifhed by the
procefs, which was continued two days, and the blood
changed five or fix times.

The nitrous air loft a great portion of it's power of
diminifhing, *i. e.* phlogifticating common air: for now
two meafures of common air and one of this occupied
the fpace of two meafures and a quarter, inftead of one
meafure and three quarters.

The inflammable air, though ftill inflammable, was
rendered in fome degree wholefome by the procefs; being
after this confiderably diminifhed by nitrous air, which is
a ftate to which it is brought by agitation in water, and
which, continued longer, deprives it of it's inflammability
likewife. Hence, in both thefe cafes, the red blood, by
becoming black, received phlogifton from thefe two kinds
of air. As to phlogifticated air, Dr. Prieftley only ob-
ferved, that after a few hours expofure to red blood it
was fenfibly, but not much, diminifhed by nitrous air,
which otherwife it would not have been in the leaft de-
gree. This blood, however, was of the lighteft colour,
or the moft free from phlogifton, of any he had feen:
and he has tried the fame thing, without fuccefs, with
blood of a lefs florid colour, though as florid as the com-
mon air could make it. But as the proper function of the
blood is not to receive (meeting with no phlogifticated air
during circulation), but to communicate phlogifton to air,
there is not the fame reafon to expect that air will be
mended by red blood, as that it will be injured by black
blood. Dr. Prieftley had imagined that, fince black blood
contains more phlogifton than red blood, a fimilar dif-
ference would have appeared in the air produced from
them, either by being fimply diffolved in fpirit of nitre,
or when dried and made into a pafte with this acid.

But the difference was too fmall to be fenfible to this kind of teft. He ufed blood from the vein of a fheep, and from it's carotid artery. The quantity of air from the pafte was very great, and produced irregularly, as is the cafe when produced by a folution in fpirit of nitre without drying. Half the produce was fixed air, and the reft phlogifticated, except that a candle burned in it with a lambent blue flame. From this experiment, however, it is evident that even the moft florid blood contains a confiderable quantity of phlogifton, for otherwife this air would have been dephlogifticated. He found great difference in the conftitution of blood, with refpect to it's property of being affected by the influence of the air, fome becoming very foon of a light florid colour, and the ftratum of this colour foon growing very thick: others, in the moft favourable circumftances, continued much darker, and the lighter colour never penetrated far.

Being convinced afterwards of the reception of dephlogifticated air into the blood, befides the emiffion of phlogifton from it, Dr. Prieftley wifhed to determine *how much* of the dephlogifticated air enters the blood, a part of it being employed in forming the *fixed air*, which is the product of refpiration, by it's uniting with the phlogifton difcharged from the blood.

To determine what proportion of dephlogifticated air, deftroyed during refpiration, is employed in forming fixed air, it was neceffary to afcertain the proportion of dephlogifticated air and of phlogifton in the compofition of fixed air. He therefore

Heated charcoal of copper in 41 oz. m. of dephlogifticated air, of the ftandard of 0.33, till it was reduced by wafhing in water to 8 oz. m. of the ftandard of 1.33. Again, he heated charcoal of copper in 40.5 oz. m. of dephlogifticated air, ft. 0.34, till it was reduced to 6 oz. m.

ft. 1.76; and in each there was a lofs of 6 grs. of the charcoal of copper : fo there cannot be more than 6 grs. of phlogifton in 33 oz. m. of fixed air; hence very little more than one fourth of the weight of fixed air is phlogifton.

He heated perfectly well burnt charcoal of wood in 60 oz. m. of common air, and found one-fifth of the remainder to be fixed air, the refiduum, ft. 1.7. Laftly, he heated $8\frac{1}{2}$ grs. of perfect charcoal in 70 oz. m. of dephlogifticated air, ft. 0.46, when it ftill continued 70 oz. m. ; but after wafhing in water it was reduced to 40 oz. m. ft. 0.6. and the charcoal then weighed $1\frac{1}{4}$ gr. : fo that from thefe experiments with common charcoal, as well as from thofe with charcoal of copper, about one fourth of the weight of fixed air is phlogifton, and confequently the other three fourths are dephlogifticated air.

Dr. Prieftley then wifhed to afcertain the quantity of fixed air formed in refpiration from atmofpherical and dephlogifticated airs, in order to determine if any part remained to enter the blood, after forming this fixed air.

For this purpofe he breathed in 100 oz. m. of atmofperical air, ft. 1.02, till it was reduced to 71 oz. m., and by wafhing in water to 65 oz. m. ft. 1.45. The computations made as before, it will appear that, before the procefs, this air contained 67.4 oz. m. of phlogifticated air, and 32.6 oz. m. of dephlogifticated air ; that after the procefs there remained 53.105 oz. m. of phlogifticated and 11.895 oz. m. of dephlogifticated air, and there were only 6 oz. m. of fixed air produced, for the quantity abforbed during the procefs could only have been very inconfiderable. It will therefore be evident, that in this experiment 20.7 oz. m. of dephlogifticated air, which would weigh 12.42 grs., difappeared : whereas all the fixed air that was found would only have weighed 4.4 grs.

and one fourth of this being phlogiston, the dephlogisti-
cated air that entered it would have weighed only 3.3 grs. :
confequently 9.12 grs. of it muft have entered the blood ;
which is three times as much as that which did not enter,
but was employed in forming the fixed air in the lungs.

He breathed in 100 oz. m. of dephlogifticated air,
ft. 1.0 till it was reduced to 58 oz. m., and by wafhing to
52 oz. m. ft. 1.75, with two equal quantities of nitrous air.
The computations being made, it will appear, that before
this procefs this air contained 66 oz. m. of phlogifticated
and 34 oz. m. of dephlogifticated air ; and after the pro-
cefs there were 30.368 oz. m. of phlogifticated, and
21.632 oz. m. of dephlogifticated air. In this cafe, there-
fore, the dephlogifticated air that difappeared was
13.3 oz. m., weighing 7.8 grs., and the fixed air was
6 oz. m., weighing 44 grs. : fo that here alfo about three
times as much entered the blood as did not.

Thefe experiments he repeated, and always with the
fame refults ; the greater part of the dephlogifticated air,
but never the whole, paffing the membrane of the lungs,
and entering the blood.

Dr. Prieftley is of opinion that part of the phlogifti-
cated air entered the blood as well as the dephlogifticated,
the dephlogifticated air confumed not being of the pureft
kind. He thinks it very probable, that the deficiency of
phlogifticated air was owing to the greater proportion of
it in the lungs after the procefs than before.

When he breathed dephlogifticated air that was very
pure, he generally found lefs lofs of phlogifticated air,
and in one cafe there appeared to be an increafe of it ;
but there will always be fome uncertainty in the refults of
the long continued refpiration of any kind of air, as the
operation becomes laborious at laft, and the quantity of
air infpired and expired is therefore greater than at firft.
Being aware of this circumftance, he endeavoured to

obviate it's effects by leaving off with his lungs, as nearly as he could judge, in the fame ftate of diftenfion as when he began, which was always after a moderate expiration; fo that two or 3 oz. meafures would have made a very fenfible difference, as will be found by actual trial.—Such are the ideas of this celebrated philofopher on the function of refpiration.

The two great Swedifh chemifts appear to differ from Prieftley. Bergman and Scheele affirm, that the lungs, or the blood they contain, abforb phlogifton from the atmofpheric air, inftead of rendering it, and they have fupported this opinion by very ingenious experiments ; fo that, according to them, the atmofpheric air, being deprived of it's phlogifton by the lungs, becomes incapable of entertaining life by ferving refpiration.

This ingenious Italian philofopher is of opinion, that he has proved, from experiment, that not only phlogifton is feparated from the lungs, but that fixed air is alfo difengaged from them; of which laft fact he looks upon himfelf to be the difcoverer. The office of refpiration, according to Fontana, is that of depriving the blood of a fuperabundance of it's phlogifton. He thinks that the caufe of fuffocation in refpired air arifes from two caufes ; for, fince the air is found to be compofed of two parts, viz. fixed and phlogifticated airs, the fixed air acts upon the lungs and deftroys life, becaufe it is not only incapable of fupporting life, but acts as a real poifon, and may be called a pofitive caufe ; and the phlogiftic air cannot entertain life, although innocent of itfelf, poffeffing no active power : but the animal dies in it merely through want of atmofpheric air ; and this may be called a negative caufe. He thinks that one part of the fixed air expired by the lungs ought not to be attributed to the pulmonary phlogifton, as is generally believed, but that it is generated in the animal machine ; whilft Landriani, in

(margin notes:) Bergman. Scheele. Fontana. Landriani.

oppofition, agrees with others, that it arifes from the ex-
pired phlogifton uniting with the atmofpheric air.

Lavoifier, from his experiments on different airs and
on the air of the atmofphere, found that dephlogifticated
air might be wholly converted into fixed air by the addition
of powdered charcoal; and he read a paper to the Academy
upon this fubject in 1775 : he thought therefore that refpi-
ration might be one procefs by which this is brought about;
and having found that the atmofphere we breathe contains
about one fourth part of vital air, and three fourths of
azot gas, he fufpected that the dephlogifticated air, when
taken into the lungs, is thrown out again in the form of
fixed air ; and that the other part, which enters the lungs,
and paffes from them nearly in the fame ftate, without
any alteration, is merely paffive.

Sufpecting, therefore, the theory of his contemporaries,
and finding it contradictory to a great number of pheno-
mena, he proceeded on a different plan, and was, by the
confequences of his experiments, led to form different
conclufions.

Experi-
ments of
Lavoifier to
determine
the fpecies
of altera-
tion the air
undergoes
from refpi-
ration.

In order to know the fpecies of alteration which hap-
pens in the air after having been breathed by animals, he
introduced a guinea-pig under a glafs bell which con-
tained 248 inches of oxygen gas. The glafs was placed
over mercury, and the animal left it in an hour and a
quarter.

To render the comparifon more eafy, he fuppofes
the quantity of oxygen gas to have been a cubic foot, or
1728 cubic inches, and calculates the refults. When the
animal was withdrawn from the glafs, the number of
inches was reduced to $1672\frac{1}{2}$, which makes a diminution
of $55\frac{1}{4}$ inches : there were found at the fame time $229\frac{1}{2}$
inches of carbonic acid gas, as appeared by the introduc-
tion of cauftic alcali; the reft was pure vital air.

By converting thefe volumes into weight, the quantities of air under the glafs will amount to

	oz.	drac.	grs.
Vital air	1	. 2 .	$1\frac{3}{4}$
Carbonic acid gas	0	. 2 .	15

Total ....1 . 4 . $16\frac{3}{4}$

Hence the air in this experiment, although diminifhed by about $\frac{1}{32}$d of it's volume, was increafed in abfolute weight ; from which, according to this philofopher, it refults,

1ft. That air extracts fomething from the lungs during refpiration.

2d. That the fubftance extracted, combining with vital air, forms carbonic acid gas ; and fince it is known that there is no other fubftance but carbon poffeffing this property, it follows, that by the procefs of refpiration a real carbonaceous matter is extracted. But this increafe of weight, which appears to be only 21.87 grs., is really much more confiderable than at firft appears credible ; for in the above experiment only $229\frac{1}{2}$ inches of carbonic acid gas were formed. Now, after fome very exact experiments, it has been found by Lavoifier that 100 parts of carbonic acid gas in weight are compofed of 72 of vital air, and 28 of carbon : hence the 229.5 inches of carbonic acid gas obtained, contain

	grs.
Of vital air	11.484
Of carbon	4.466

The 11.484 grs. of vital air amount in cubic inches to $229\frac{2}{3}$: if, therefore, there was only fufficient vital air ufed to form the carbonic acid gas, the remaining quantity ought to be 1728—$229\frac{2}{3}$.

	$1498\frac{1}{3}$
There was found only	$1443\frac{2}{3}$
Confequently a deficit of..........	$54\frac{2}{3}$

E 2

Hence, according to Lavoisier, independently of the vital air converted into carbonic acid gas, a portion of that which entered into the lungs did not return in an elastic state; and therefore one of two things must have happened during respiration: a portion of the vital air either united with the blood, or combined with a portion of hydrogen gas to form water. Supposing the last, it is easy after the above experiment, says this chemist, to determine the quantity of water formed by respiration, and the quantity of hydrogen gas extracted from the lungs. For since, to form 100 parts of water, 85 parts of vital air in weight and 15 of hydrogen gas are employed, it follows, that with the 54 inches of vital air found wanting, 32.25 of water ought to be formed; and that there were $4\frac{5}{6}$ grains of hydrogen gas disengaged from the lungs of the above-mentioned animal. From this and other

His conclusion. experiments he was led to conclude that respiration only acts on the portion of oxygen gas contained in the atmosphere; that one portion is converted into carbonic acid gas, whilst the other is employed to form water.

Composition of the atmosphere. According to Lavoisier, the atmosphere is composed of 0.27 of pure air and 0.73 of azot; but it had long been suspected by de la Metherie that fixed air likewise made a part of it, and Humboldt has since proved he was right in his conjecture. He found that in it's ordinary quantity it amounts to 0.014, that it's maximum is 0.018, and it's minimum 0.005; and this quantity is so strongly allied to the azot and oxygen as not to be separated by the greatest portion of water the atmosphere contains. According to this chemist, it appears likewise, that it is not the quantity alone of oxygen contained in the atmosphere that renders it proper for respiration, as in mines he found air which extinguished light and killed animals, that contained even 0.27 of oxygen.

Hence he affirms it is not the default of oxygen that

renders noxious atmofpheres or mofets fo mortal, but the
manner in which this oxygen is combined. The atmo-
fphere therefore is not a fimple mixture of 0.27 of oxygen,
0.72 of azot, and 0.01 of carbonic acid, but there is a
real combination of all thefe principles united to the
aqueous portion: he found that the oxygen the atmofphere
contains varied from 0.23 to 0.29.

It appears there was no experiment of importance to
determine the quantity of air the lungs contain, until that
made by Borelli in the middle of the laft century. Hav-
ing breathed through a glafs tube of which the volume
was afcertained, and of which one end was immerfed in
fome bubbles of foap, he found the quantity of air re-
ceived into the lungs in one infpiration to be about 15
cubic inches ; and towards the end of the experiment to
be between 18 and 20 cubic inches. This experiment
however is liable to objection ; for it is, according to
Menzies, not only inaccurate, from the friction and other
caufes, but it is only the meafure of one infpiration.

*Experi-
ments to
determine
the quantity
of air the
lungs con-
tain.*

The next author is the celebrated Jurin. He fufpended
a weight to the lower part of a bladder, previoufly moift-
ened ; and having fixed a tube of about an inch diameter
in the upper part, he ftopped his noftrils and infpired the
air of the bladder gently, during three minutes, the
weight remaining all the while on the table. He then
plunged the bladder, with the air enclofed in it, and the
weight fufpended to it, into water contained in a cylin-
drical-veffel : he then marked the height to which the
water rofe. Having now fqueezed the air out of the
bladder, he again plunged it into the water with the
weight. The difference of the height to which the water
rofe in both thefe cafes was eafily calculated. Having
repeated the experiment ten times, and added the quan-
tities together, the tenth part of the fum total, or the pro-
portional difference of the height to which the water rofe

Jurin.

in both cafes, was found equal to 35 cubic inches, which
is the volume of air contained in the bladder ; and having
added about the twelfth part, or three inches, on account
of the condenfation of the air from the coldnefs of the
water, as it was winter, it amounted to 38 cubic inches. He
added a little, both on account of the preffure of the water
on the bladder, and of the moifture which is expelled
with the air, and foon condenfed by the coldnefs of the
water and of the bladder.   He then calculated the quan-
tity of air, expelled by a moderate expiration in the fpace
of three minutes, at 40 cubic inches.   In the ftrongeft
expiration he expelled 125 cubic inches in the fpace of
a minute; but in a ftrong expiration, continued nearly
until fuffocation, he expelled 220 cubic inches from the
lungs. Hence it follows that there is more air in the lungs
than can be expelled by an ordinary expiration.

This experiment proves that the quantity of air ufually
Hales, &c. expired is equal to 40 cubic inches.   The accurate Hales,
Haller, and Sauvages, who have repeated thefe experi-
ments, have agreed that the refult was the fame.   But
according to Menzies, as it is only the meafure of one
infpiration, it lies open to the fame objection as the
former.

Dr. Good-   This was alfo attempted by Dr. Goodwin.   He endea-
win.   voured to breathe from a veffel full of air, joined by
means of a tube to another full of water, fo that a certain
volume of water, equal to that of the air infpired, might
get into the place of the latter after each refpiration ; for
the volume of water, fubftituted to that of the air infpired,
muft be equal to that of the air confumed in infpiring.

Having contrived an apparatus for this purpofe, an
adult of a middle fize, and in good health, endeavoured
to refpire as naturally as poffible from this pneumatic
veffel, and the

> Firft time, he infpired 3 cubic inches ;
> Second time, ... $2\frac{1}{2}$

Another perfon of the fame ftature endeavoured to breathe out of the veffel.

At the firft infpiration, he breathed $3\frac{1}{5}$ cubic inches;

At the fecond, ... $2\frac{3}{4}$.

But as the difference of the refult of both thefe experiments might be fuppofed to proceed from the different degree of attention, he varied the experiment in this manner. The fame man infpired and expired thirty times out of the fame veffel, and as nearly as poffible with the fame degree of exertion; and on calculation the average quantity of air of each refpiration was found to be $2\frac{3}{4}$ cubic inches.

Having repeated the fame experiment with the greateft care, the average quantity of each refpiration was found to be 3 cubic inches.

Another man of the fame ftature breathed 30 times from the fame veffel, and in the fame manner, and the average was $3\frac{1}{5}$ cubic inches. Hence it follows that the greateft quantity of air received into the lungs during each natural refpiration does not exceed $3\frac{1}{6}$ cubic inches; which is much lefs than what Hales and Jurin had calculated.

In the laft differtation of Dr. Goodwin, it appears that a dull kind of pain was felt in the cheft before the man had finifhed the number of infpirations. Having removed the tube from his mouth, it was neceffary to make a deep infpiration; which appears to Menzies to prove, that the quantity of air received into the lungs was not fufficient for the purpofes of refpiration. This defect however is attributed by the author to the imitation of natural refpiration, which could not counterbalance the difficulty of raifing water contrary to it's natural gravity. As an attempt to breathe in the open air would not give the meafure of an ordinary infpiration from the machine, it was neceffary to affift the action of the lungs,

by which the quantity received was much increafed; as is evident from the following experiment, in which three perfons of ordinary ftature infpired from the machine 30 times fucceffively, and took in as much air at each time as the fenfations in the breaft feemed to require. The average quantity of air taken into the lungs at a fingle infpiration

By the firft, was 12 cubic inches.

second, .. 14

third, .. 11

Thus Dr. Goodwin concludes the quantity of air infpired to be equal to 12 cubic inches, which are dilated by heat to 14; and as the quantity of air remaining in the lungs, after an ordinary expiration, is near 109 cubic inches, he concludes, the proportion of the dilatation of the lungs, before and after a healthy infpiration, to be as 109 to 123.

Menzies.   Dr. Menzies, who is the laft that has made any experiments of this nature, although he is of opinion that Dr. Goodwin has come, very near the point, yet in the different experiments on the fubject he found no confidence could be placed in the method he employed, on account of the inaccuracies it was liable to; and he freely confeffes it was by chance he firft difcovered them. The method which Dr. Menzies ufed feems to be fimilar to that indicated by Boerhaave.

It confifts in being placed up to the neck in water, and judging of the dilation of the lungs from the afcent and defcent of the water. Dr. Menzies therefore procured a hogfhead, the top of which had an opening fufficiently large for the head to pafs out; and a cylinder was fitted about his neck up to the chin, by which the rifing and falling of the water during refpiration might be calculated.

1ft Experiment.   A healthy man, five feet eight inches high, was fhut

up in this hogfhead, which was filled with water heated
to 90° of Fahrenheit, as far as that part of the neck that
was beft fuited to meafure the difference of afcent and
defcent. This difference was about 1.25 inches. His
pulfe before and after immerfion beat 64 or 65, and his
refpirations were 14 or $14\frac{1}{2}$ in a minute, and they con-
tinued the fame all the time he remained, which was
two hours and upwards, during which the afcent and de-
fcent of the water were $1\frac{25}{100}$ inch at leaft: but when he
made a deep infpiration, fo much air rufhed into the
lungs that the water paffed out through the cylinder; but
as the area of the cylinder was 55.41 fquare inches,
and the area of the neck 18; 55.41—18×1.25=46.76
cubic inches, the quantity of air ufually refpired by this
man. This was thrice repeated with the fame refult;
but to prevent miftake he was made to breathe through
an allantoid.

This allantoid contained 2700 cubic inches, which in
many trials he filled with 58 expirations, giving 46.55
cubic inches as the quantity of air expired; and this cal-
culation is very near the preceding one. But as the re-
fpirations of this man appeared to be never more than
14 and $14\frac{1}{2}$ in a minute, it was probable he infpired more
air than other men of the fame ftature. To afcertain
this, and to be able to eftimate the average quantity of air
infpired, it was neceffary to examine the refpiration of a
man of fmall ftature.

Another man, therefore, only five feet and an inch 2d Experi-
high, was fhut in the fame hogfhead; the pulfe beat 72, ment.
and the number of refpirations was 18 in a minute. The
water was heated between the 85th and the 90th of Fah-
renheit. The difference between the afcent and defcent
during the long time he remained was 0.95 of an inch, or
in vulgar fractions $\frac{95}{100}$ of an inch. The area of the cy-
linder was equal to 57.012 inches, and the area of the

neck to 14.0837 inches. Hence 57.012—14.0837 × 0.95
=40.781 cubic inches, is the quantity of air taken into
the lungs by a common refpiration. This was confirmed
by his breathing into the allantoid, which gave from 38 to
40 cubic inches, the meafure of a common infpiration.
So that, if half the quantities of the two experiments be
taken, there will be 43.77 cubic inches, the average quan-
tity of air refpired. The afcent and defcent of the water
were carefully marked by means of a glafs tube inferted
into the top of the hogfhead, on which a fcale of degrees
was cut ; and on account of the attraction between the
water and the fides of the tube $\frac{1}{20}$ was fubtracted ; and if
on account of the dilatation of the air by the heat of the
lungs $\frac{1}{472.5}$ for every degree of heat be fubtracted, the
quantity of air infpired may ftill be computed at 40 cubic
inches.

Dr. Goodwin fuppofes that only 109 cubic inches re-
main in the lungs after an ordinary expiration, and that
the proportion of their dilation after an ordinary expira-
tion is to that of their dilatation after an ordinary infpira-
tion as 109 to 123; but Dr. Menzies has remarked, that
after an ordinary expiration a man could ftill expel
70 cubic inches of air from the lungs. Hence after fuch
an expiration only 39 cubic inches of air will remain.
" Without doubt then," fays Dr. Menzies, " as appears
" from another experiment (Goodwin's Connexion of
" Life with Infpiration, p. 46), Dr. Goodwin fuppofes
" that 109 cubic inches of air remain in the lungs after
" an extraordinary expiration ; but as we have found
" 70 cubic inches to be the difference between an ordi-
" nary and an extraordinary expiration, this number
" added to the former, or to 109, will give 179, as the
" quantity of air remaining in the lungs after an ordi-
" nary expiration. Now the former experiments
" fhow, that the quantity of air expelled by an ordinary

" expiration is equal to 40 cubic inches: consequently,
" if this be added to 179, we shall have 219 cubic inches
" as the quantity of air contained in the lungs before
" expiration : hence the dilatation of the lungs before and
" after an ordinary expiration will be as 219 to 179 : or,
" in other words, the thorax will be increased by a
" quantity of air nearly equal to a cube of $3\frac{1}{2}$ inches;
" which, if we confider how much the thorax and abdo-
" men are dilated by an extraordinary infpiration, feems
" very trifling. The difference between an extraordinary
" expiration, or one made with fome effort, and an extra-
" ordinary infpiration, I have found to exceed 200 cubic
" inches."

As the atmofpheric air undergoes a change by refpira- *Dr. Good-*
tion in the proportion of it's conftituent parts, the de- *win's ex-*
periments
phlogifticated air being diminifhed, the fixed air increafed, *to afcertain*
the degrees
whilft the phlogifticated remains the fame ; Dr. Goodwin *of change*
was defirous of afcertaining the particular degree of thefe *the parts of*
the atmo-
changes : he therefore began by finding the proportion *fphere un-*
dergo in re-
of the airs in 12 cubic inches of atmofpheric air ; which *fpiration.*
being done, he infpired an equal volume of the fame air,
and then expired it into a glafs receiver, and analyfed the
whole quantity. This having been repeated feveral
times, the medium was as follows :

	Parts.		Parts.
The volume of air taken into the lungs at a fingle infpi- ration contained of phlogif- ticated air	80	The volume of air expelled from the lungs by the next fuc- ceeding expiration contained of phlogifticated air	80
Dephlogifticated air	18	Dephlogifticated air	5
Fixed air	2	Fixed air	13
	100		98

He found this diminution of the dephlogifticated air was
fometimes $\frac{1}{50}$th or $\frac{1}{60}$th part.

He then attempted to find if this diminution of the one and increase of the other be constant and uniform in the same volume of air several times respired; for which purpose, he first examined the diminution of the dephlogisticated air, by breathing a quantity of air several times from a glass receiver inverted in water; and by mixing a small quantity of this same air, after every expiration, with an equal quantity of nitrous air in Fontana's eudiometer, in which the quantity of dephlogisticated air would be indicated by the diminution of volume in the eudiometer: he therefore passed 12 cubic inches of atmospheric air into a glass receiver inverted in water, and put a measure of it into this instrument, where it occupied 100 parts: he then added an equal measure of nitrous air, and the whole volume of 200 parts was diminished to   -   -   -   -   -   -   -   -   144

Then he inspired the whole of the volume from the receiver, and expired it in the usual time; and on trying an equal portion of it in the instrument, the 200 parts were diminished to   -   -   158

After the second expiration, to   -   -   163
After the third, to   -   -   -   167
After the fourth, to   -   -   -   170
After the fifth, to   -   -   -   171

2dly. To determine whether the addition or increase of the fixed air be uniform and constant in several successive respirations, he enclosed 12 cubic inches of air in an inverted receiver, and breathed it through a glass tube six times in succession; when, on being examined with lime water after the last expiration, it contained 15 parts of fixed air: on repeating the experiment, the quantity of fixed air was 13 parts: hence the diminution of the dephlogisticated and the increase of the fixed air is constant and successive in the same quantity of air frequently breathed; but the changes in the successive respirations

bear no proportion to the changes in the firſt. Dr.
Goodwin, finding therefore theſe changes ſo conſtant and
uniform, ſuſpected they muſt be connected with ſome
correſponding changes in the lungs, equally conſtant and
uniform, which he found to be in the blood.

Count Morozzo, in order to prove the length of time
different animals were able to live in different airs, ſo as
to be able to form a compariſon, made the following ex-
periments :

The oxygen gas he uſed was extracted from red pre- Experi-
cipitate and nitre, which he found to be of equal purity : Morozzo,
the animals were ſparrows and rabbits, of an adult ſtate, on expoſing
that he might be able to compare the reſults, having ob- different
ſerved that animals lived a longer or a ſhorter ſpace of air.
time in a vitiated air according to their age; which dif-
ference ceaſes on their arrival at maturity. He uſed the
method employed by Dr. Cigna of expoſing a ſucceſſion
of animals to the ſame gas, and found the reſults to be
perfectly ſimilar : he found that,

							Hours.	Min.
In atmoſpheric air, the 1ſt ſparrow lived about	-						3	—
	2d	-	-	-	-		—	3
	3d	-	ſcarcely	-			—	1
In dephlogiſticated air, the 1ſt ſparrow lived	-	-	-	5	25
	2d	-	-	-	-		2	10
	3d	-	-	-	-		1	30
	4th	-	-	-	-		1	10
	5th	-	-	-	-		—	30
	6th	-	-	-	-		—	47
	7th	-	-	-	-		—	27
	8th	-	-	-	-		—	30
	9th	-	-	-	-		—	22
	10th	-	-	-	-		—	21

On repeating his experiments in veſſels of equal ſize,
he found that animals lived four and even five times
longer in dephlogiſticated than in common air; that after

the death of the animal a lighted candle was immediately
extinguifhed in the atmofpherical air, but preferved it's
brilliancy and vivacity in the dephlogifticated air, as if it
had undergone no change; which is contrary to what
Dr. Cigna obferved, that common air when vitiated by
refpiration extinguifhes flame a long time before animal
life. He remarks with Dr. Prieftley, that animals appear
to be more gay and active in oxygen gas than in atmo-
fpherical air; and that, when their refpiration appears
troubled, they do not gafp for breath fo much, nor is
their death accompanied by fuch violent convulfions as in
atmofpheric air; and that the duration of their life in
oxygen gas did not decreafe in any marked proportion
from the introduction of the fifth.

Having obferved that oxygen gas, in which different
animals have fucceffively died, is ftill in a ftate of fup-
porting animal life a confiderable time, and flame with
great vivacity, he was defirous of anfwering the follow-
ing queftions:

1. To find the duration of animal life in dephlogifti-
cated air, in which a candle had been extinguifhed; and
he found animals lived in it nearly as long as in pure
oxygen gas.

2. To difcover whether a lighted candle would burn in
the oxygen gas in which flame had been extinguifhed,
and he found it would not. In equal capacities, flame
exifted five minutes in oxygen gas, and only forty feconds
in atmofpheric air.

In order to difcover the leaft variations, Morozzo ufed
veffels of a larger capacity, containing forty pounds
of water, and larger animals, fuch as rabbits; and he
found that,

	H.M.					Inch.Lin.
In atmofpheric air, the 1ft lived	4 33,	and the abforption			' 0	9
2d -	0 13,	-	-	-	-	0 4
3d -	0 5	-	-	-	-	0

				H. M.				Inch. Lin.	
In oxygen gas	-	1ft	-	10 3,	-	-	-	2	0
		2d	-	3 57,	-	-	-	1	8
		3d	-	4 30,	-	-	-	2	2

He remarked with Dr. Prieftley, that quadrupeds live longer than birds in vitiated air, from being accuftomed to breathe nearer the ground, where the air is not fo pure as in the higher regions; and he lays it down as a rule, that animals in oxygen gas confume a quantity in proportion to common air as 5 to 1 ; which is the fame proportion as that of the greateft durability of their lives.

From expofure of animals in different airs, he found,

1. That the duration of animal life was in proportion to the greater quantity of oxygen gas the airs contained. Conclufions.

2. That in all where there was an equal part of oxygen gas, they lived confiderably longer than in common air, except in the air vitiated by the vapour of charcoal, in which a fparrow lived only 24 minutes, and in fixed air 38 minutes.

3. That in all thofe of which one-third was oxygen gas, animal life was nearly equal to what it was in common air, except in the two laft cafes.

4. Gafes and infectious airs appear to be fatal in the order following:

Inflammable gas of marfhes - - - } nearly equal.
Air vitiated by vapour of fulphur - -

———.—-—by burning charcoal - -
———.—-—by a mixture of iron filings
and moiftened fulphur - - - -
Inflammable gas from iron and vitriolic acid } nearly equal.
Fixed air - - - - - - - -
Air vitiated by animal refpiration - -

Dr. Prieftley has likewife made fome experiments on animals in noxious airs; from which he found that animals, on being put into air in which other animals have died, Prieftley's experiments on animals in noxious airs.

almoſt always die in convulſions : they are ſometimes af-
fected fo fuddenly as to be irrecoverable after a ſingle in-
ſpiration, although withdrawn immediately, and every
care taken to recover them. They are affected in the
ſame way in every other noxious air; ſuch as fixed air,
inflammable air, air filled with fumes of ſulphur, in-
fected with putrid matter, in which a mixture of iron
filings and ſulphur has ſtood, or in which charcoal has
been burned, or metals calcined, or in nitrous air. Ac-
cording to Dr. Prieſtley, animals become habituated by
degrees to the noxious air; for he frequently found, that
when a number of mice had been confined in a given
quantity of air, a freſh mouſe being introduced to them
has been inſtantly thrown into convulſions, and died. It
is evident, therefore, that if the experiment of the black
hole at Calcutta were to be repeated, a man would ſtand
the better chance of ſurviving it who ſhould enter at the
firſt than at the laſt hour. Dr. Prieſtley has alſo obſerved,
that young mice will live much longer than old ones; or
than thoſe which are full grown, when they are confined
in the ſame quantity of air. He has known a young
mouſe to live ſix hours in the ſame circumſtances in
which an old mouſe has not lived one : hence the uncer-
tainty in making experiments of this kind, where a fre-
quent repetition is neceſſary to depend upon them.

Having given ſome account of the ancient and modern
opinions of reſpiration in general, of the experiments that
have been made on the effects of reſpiration upon air, of
the changes it ſuffers from this proceſs, of the formation
of new ſubſtances found in expired air, of their propor-
tions, of the opinions of ſeveral chemical phyſiologiſts
upon the quantity of air the lungs contain, and of the ex-
periments made upon animals in different ſpecies of airs,
the next part of the ſubject relates to the colour the blood
receives during the reſpiratory proceſs, beginning with

fóme account of the opinions of different philofophers upon this fubject.

Colour of the Blood.—The ancients muft undoubtedly have obferved, that the furface of blood, after having been drawn from the body and left to repofe, changed from a dark to a florid red colour, and that underneath it re-mained black; but they could have had no juft idea of the caufe of this change. It appears, that, among the mo-derns, Mayow was the firft whofe conjectures were confor- Mayow. mable to the lateft experiments. He fays, that the fluid red colour of the blood is produced by the introduction of the nitroaerial fpirit from the atmofphere; for where the blood is not expofed to this, it is black. As, how-ever, this celebrated author's publication was fcarcely known to exift previous to it's being introduced to public notice by Dr. Beddoes, nobody, unlefs we accept Lower, at-tempted to account for this difference, or the caufe of the colour. Even fo late as the time of Haller all was con- Haller. jecture: this celebrated phyfiologift, on comparing the blood of an adult with that of the fœtus, which is defti-tute of the florid rednefs, only informs us that it was ac-quired in the lungs. The common opinion was, that the change of blood, on ftanding, arofe from it's containing two kinds of particles, red and black; and that the black, from their greater fpecific gravity, fell to the bottom, whilft the red particles remained at the furface.

Cigna of Turin, at length, having paid great atten- Cigna. tion to this fubject, publifhed a memoir in the firft volume of the *Mifcellanea Taurinenfia*, in which he very well ac-counts for this red colour of the blood, clearly proving it to be caufed by the contact of air. He found, that, on covering the blood with a little oil fo as to defend it from the atmofphere, it remained black throughout; but when he took away the red part, and expofed the lower *laminæ* to the air, which were black, they alfo became

succeffively red, till the whole mafs had acquired this co-
lour. At the requeft of Cigna, father Beccaria was in-
duced to try the effect of expofing blood in the vacuum
caufed by an air-pump, and he found that it always re-
mained black, but became red on expofing it again to the
atmofphere. Cigna concludes by obferving, that it is
not eafy to account for the lower part of a mafs of blood
becoming black, whether it arifes from the air it has im-
bibed efcaping from it, or from it's depofiting fomething
faline, neceffary to contribute to it's rednefs, or from the
preffure of the atmofphere; but he feems to think, that air
mixed with blood, and interpofed between the globules,
preferves it's rednefs; but that by concreting it is expelled
from it, or becomes fo fixed as to be incapable of making
it red. This opinion, he imagines, is rendered in fome
meafure probable, by the increafed denfity of concreted
blood, and by the emiffion of air from other fluids in a
concrefcent ftate. In another, memoir, he doubts whether
the change of colour in the blood takes place in the lungs,
but if it does, he is inclined to afcribe it to the *evaporation*
from the blood in the lungs; and though he always found
the colour of the blood was changed by the contact of air,
yet when he confidered that evaporation muft neceffarily
attend the contact of air, he fuppofed that this effect might
equally be attributed to it. But he acknowledges con-
firmation by experiments is neceffary to this hypothefis.

Hewfon. Other experiments were made by Hewfon. He found
that a folution of nitre changed dark-coloured blood to
the moft beautiful red; but is of opinion that this cannot
arife in the lungs, fince the air contains no nitre; and he
found moft of the neutral falts in fome meafure produced
the fame effect. He was certain, however, that, as the
colour of the blood is changed by air out of the body, the
air is the immediate caufe of the fame change in the body;
and this change in the venous and arterial blood is pro-

duced in the lungs, he affirms, from experiments in which he diſtinctly ſaw the blood of a more florid red in the left auricle of the heart than in the right; but how the effect is produced he thinks is undetermined.

The cauſe of this change was determined by Dr. Prieſt- Dr. Prieſt-
ley; but he attempts to explain it according to the phlo- ley.
giſtic ſyſtem. He endeavoured to find whether blood was
of ſuch a nature as to retain the power of phlogiſticating
air when congealed, and out of the body, that it has when
fluid and in the body; and the experiment anſwered his
expectation. Having taken the blood of a ſheep, and let
it ſtand till it was coagulated, and the ſerum ſeparated
from it, he introduced pieces of the craſſamentum, con-
tained in nets of open gauze or of wire, ſometimes
through water, and ſometimes through quickſilver, into
different kinds of air, and always found that the blackeſt
parts aſſumed a florid red colour in common air, and
more particularly in dephlogiſticated air, and in leſs time;
whereas the brighteſt red blood became preſently black in
any kind of air unfit for reſpiration, ſuch as fixed, inflam-
mable, nitrous, or phlogiſticated airs; and after becom-
ing black in the laſt of theſe kinds of airs, it regained it's
red colour on being again expoſed to common or dephlo-
giſticated airs; the ſame pieces becoming alternately black
and red by being transferred from phlogiſticated to de-
phlogiſticated air, and *vice verſa*.

In theſe experiments, Dr. Prieſtley is of opinion, that
the blood loſes it's black colour by giving it's phlogiſton,
which is the cauſe of it, to the air; and that it receives it
again on being expoſed to the other airs containing this
principle. He thinks that the blackneſs of the blood may
ariſe from other cauſes than it's acquiring phlogiſton, as
in vacuo; and ſuch he found to be the caſe when it was
covered two inches and a half with ſerum, but regained it's
florid colour again on expoſure to the open air. He expoſed

pieces of the fame mafs to nitrous and inflammable as well
as fixed airs; they all became black, but that in the in-
flammable the leaft fo; but none of them recovered their
fluid colour in the open air; one, however, in fixed air,
recovered it in dephlogifticated air. The deeper the co-
lour, the more the phlogifton it contains, and *vice verfa.*
As it might be objected to this hypothefis of Dr. Prieft-
ley, that the blood never comes into actual contact with
the air in the lungs, but is feparated from it; and that the
red globules alfo fwim in a large quantity of ferum, a fluid
of a quite different nature; in order to afcertain the effect
of thefe circumftances, he took a large quantity of black
blood, and put it into a bladder moiftened with a little fe-
rum, and, tying it very clofe, hung it in a free expofure
to the air, though in a quiefcent ftate; and the next day
he found that all the lower furface of the blood feparated
from the common air by the bladder (which is an animal
membrane like the veficles of the lungs, and at leaft as
thick), and likewife a little ferum, had acquired a coating
of a florid red colour, and as thick as if it had been im-
mediately expofed to the open air; fo that the membrane
had been no impediment to the action of the air on the
blood. He repeated the experiment without previoufly
moiftening the bladder, and with the fame refult. He
found that a piece of the craffamentum acquired the florid
colour even when covered with ferum to the depth of fe-
veral inches; but, that the flighteft covering of water or
faliva effectually prevented it's acquiring this colour, which
proves how wonderfully well the ferum is adapted as a ve-
hicle for the red globules. To fatisfy himfelf completely
that it is really the air acting through the ferum, and not
the ferum itfelf that gives the florid colour, he took two
equal portions of black blood, and put them into equal
cups, containing equal quantities of ferum, which co-
vered them to the depth of half an inch. One of thefe

cups he expofed to the air, and the other under an ex-
haufted receiver, when the former prefently acquired a
florid colour, and the other continued twelve hours as
black as the firft. It alfo remained black when expofed
to the air, and the ferum taken off. He reverfed this ex-
periment, and found that red blood became black through
the depth of two inches of ferum, expofed to phlogifti-
cated air; a confirmation that the red globules of the
blood receive and part with phlogifton by means of the
air, notwithftanding the interpofition of a large body of
the fluid in which they naturally float.

Dr. Prieftley, however, does not infer, in all cafes, that
blood becomes black by imbibing phlogifton *ab extra*;
for, if time be given it, this change may arife from *inter-
nal caufes*, as from putrefaction, which he found by ex-
perience.

Except ferum, he found that milk is the only animal
fluid through which the air can act upon blood, for black
blood became red when plunged into milk as if covered
with ferum. It becomes inftantly red in urine, which he
attributes to the faline nature of that fluid. This makes
it probable, that the rednefs of the blood is owing not
only to it's *parting* with phlogifton, but to *imbibing* the
acidifying principle from the dephlogifticated air.

As the principal ufe of the blood appears to Dr. Prieft-
ley to be derived from it's power of receiving and dif-
charging phlogifton, and the degree in which it poffeffes
this power is eafily afcertained by the eye, it might, he
thinks, be worthy the attention of phyficians; for in
cafes in which the blood is unufually black, and but little
affected by common air, perhaps breathing a purer air
might be prefcribed with advantage. In general, the
blood he procured in the city was not fo good as that got
in the country, which he attributes to the cattle having
been much driven and heated before they were killed,

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It appears from Dr. Prieftley's account, that having afterwards made fome experiments on the mutual tranf-miffion of dephlogifticated air, and of inflammable and nitrous, through a moift bladder interpofed between them, and from the opinions of others, he was foon convinced, that, befides the emiffion of phlogifton from the blood, dephlogifticated air, or the acidifying principle of it, is at the fame time received into the blood; yet he appears ftill to be of opinion, that although the application of dephlo-gifticated air to the outfide of a vein may change the co-lour in it, as Dr. Goodwyn has proved, this might have been affected, as he firft fuppofed, by the fimple difcharge of phlogifton from the blood, when it had an opportunity of uniting with the dephlogifticated air thus prefented to it.

Lavoifier and Crawford formed their opinion of the co-lour of the blood from the experiments which Prieftley and Hamilton made. The laft made three ligatures upon the jugular vein of a cat; having extracted the blood com-prehended between two of thefe ligatures, he introduced hydrogen gas into it, and detained it by clofing the ori-fice; he then united the middle ligature, and the blood be-tween the third ligature and that of the middle became in contact with the hydrogen gas. Having drawn the blood from the vein, he found it liquid, and that it had acquired a colour nearly as deep as ink. Venous blood expofed to vital air acquires the vermilion colour of arterial blood, and the vital air is vitiated. From thefe experiments, La-voifier and Crawford are of opinion, that the change of colour the blood undergoes in the courfe of circulation proceeds from it's uniting with hydrogen ; that the blood when it paffes through the lungs communicates a part of it's hydrogen to the oxygen contained in the infpired air, and that it then receives it's red colour again.

It had long been obferved by Lower (Tract. de Corde, p. 185.), in living animals, that the blood from a wound

Lavoifier and Crawford. *(marginal note)*

Dr. Good-wyn. (marginal note)

in the trunk of the pulmonary vein was florid; and know-
ing before that the blood entering the lungs by the pulmo-
nary artery is black, he concluded that it acquired this
florid colour by paſſing through the lungs; and finding
afterwards, that when the animal ceaſed to breathe, the
blood from the wound in the pulmonary vein was black,
he attributed the florid colour to the action of the air in
reſpiration. Dr. Goodwyn, ſtruck with this fact, under-
took to examine the truth of it.   He procured ſome large
dogs, removed the ſternum, and expoſed the trunks of the
pulmonary veins and arteries, ſo as to be able to diſtinguiſh
accurately the colour of the blood paſſing through them.
He then inflated the lungs with bellows, as deſcribed by
Veſalius, ſo as to imitate the natural reſpiration, and he
kept the animal alive by this proceſs a conſiderable time.
In theſe experiments he obſerved, that, during the infla-
tion, the blood in the trunks of the pulmonary artery was
black, but in the trunks of the pulmonary veins florid;
and when the inflation was intermitted for a minute, the
blood in the trunks of the pulmonary vein became gradu-
ally black, like that in the arteries.   Dr. Goodwyn like-
wiſe confirmed Lower's opinion by other experiments on
the toad and lizard, whoſe lungs conſiſt of only a tranſ-
parent bladder, with blood-veſſels ſo thin that the colour
of the circulating blood may be eaſily diſtinguiſhed
through them; and in all the examples, when the air
paſſed into the lungs; the blood in the pulmonary veſſels
became gradually florid; but when they were emptied by
preſſure, it became gradually black.

Dr. Goodwyn then inquired to what part of the air re-
ſpired this change of colour was owing, whether to the ad-
dition of fixed air ſeparated from the blood in paſſing
through the lungs, or to the action of the phlogiſticated
or dephlogiſticated air.   He found by experiment, that

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fresh drawn florid blood expofed to fixed air underwent
no fenfible change, and as black blood frefh drawn under-
goes no change of colour when expofed to dephlogifti-
cated air, he tried what the change of venous black blood
would be when expofed to dephlogifticated air, and found,
in fupport of the common affertion, that it became florid,
whilft a fmall portion of the air difappeared during the
procefs; hence he is difpofed to believe, that when the
dephlogifticated air produces this change, fomething at
prefent unknown pervades the coats of the pulmonary
veffels by the force of chemical attraction.

Dr. Goodwyn concludes that,

1. A quantity of dephlogifticated air is feparated from
the atmofpheric air in the lungs.

2. That this dephlogifticated air exerts a chemical ac-
tion upon the pulmonary blood, in confequence of which
it acquires a florid colour.

Girtanner. If arterial blood be expofed to hydrogen gas in a glafs
veffel, the quantity of gas is diminifhed, and the vermilion
colour of the blood is change to a deep colour. In this
experiment, according to Girtanner, the contrary paffes
to what it does in refpiration. The hydrogen gas in the
laft cafe unites to the oxygen of the arterial blood, to form
water, and the arterial blood being deprived of oxygen be-
comes black, and is changed into venous blood, it's deep
colour arifing from the lofs of it's oxygen. The experi-
ment of Hamilton, before quoted, is explained by Gir-
tanner in the fame way. In this cafe the blood was found
liquid, and little coagulable, which Girtanner likewife
reckons in his favour; for in his firft memoir he afferted,
that the coagulability of the liquids followed the fame
laws, and depended upon the fame principle, as the irrita-
bility of the folids, confequently the blood deprived of the
irritable principle, or of the oxygen, ought to be liquid,
i. e. little or not coagulable. This chemical phyfiologift,

after having fhown that the arguments hitherto brought
are not convincing, proceeds to bring proofs in favour of
his own theory.

1. *Venous Blood.* Six ounces of black venous blood,
drawn from the jugular vein of a fheep, were expofed to
oxygen gas under a glafs. It was inftantly changed to a
vermilion colour; the thermometer mounted a few de-
grees, and defcended again. The mercury under the glafs
arofe fix or eight lines. The blood weighed a little more
than before. This proves, according to Girtanner, that
the blood during refpiration abforbs oxygen. This was
confirmed by a fecond experiment. He opened the jugu-
lar vein of a fheep, and received the blood in a bottle
filled with oxygen gas, and the bottle when half full was
ftopped. The blood immediately became of a vermilion
colour, very fluid, and only coagulated flowly into a thick
and reddifh mafs, from which no ferum was feparated.

He injected a pretty confiderable quantity of very pure
oxygen gas into the jugular vein of a dog, which killed it
in lefs than three minutes. He found the heart more irri-
table than ordinary. The right auricle and ventricle con-
tained blood of a vermilion colour not coagulated. The
blood in the left ventricle, the aörta, and the arteries, was
of a rofe-colour, and mixed with blebs of air. This proves
that the vermilion colour is not owing to the lofs of car-
bonated hydrogenous gas in refpiration, but to the blood
combining with the oxygen gas. In this experiment, the
deep colour of the venous blood of the right auricle and
ventricle was changed into a vermilion; yet there could
be no lofs of carbonated hydrogenous gas; there was only
an addition of oxygen gas.

He injected a fmall quantity of azot gas, deprived of
fixed air by lime-water, into the jugular vein of a dog,
which died in twenty feconds. The blood of the right
auricle and ventricle was black, thick, and coagulated.

The left ventricle was of it's ordinary colour. He found
that the venous blood of a fheep expofed to azot became
black nearly as ink, and coagulated immediately ; that a
quantity of ferum was feparated, and the following day a
flight odour of ammonia was perceived on opening the
bottle.

This proves that the colour of the blood arifes from the
azot ; and the ammonia from the union of the fame azot
with the hydrogen gas of the venous blood. The colour
of the blood becoming more deep after having loft a part
of it's hydrogen, appears to prove that this deep colour is
owing to the carbon of the blood, and not to the combi-
nation of the hydrogen gas, as is thought. The venous
blood of a fheep expofed to carbonic acid gas in a bottle
immediately coagulated, became of a very deep colour,
and a great quantity of reddifh ferum feparated. A fmall
quantity of carbonic acid gas being injected into the ju-
gular vein of a dog, killed it in a quarter of an hour. The
blood of the right auricle and ventricle was thick, and in
part coagulated ; that of the left was of a much deeper
colour than ufual. This likewife proves that the deep
colour of the venous blood is not owing to the combina-
tion of hydrogen gas. One part of the oxygen of the
carbonic acid gas probably united to the hydrogen of the
blood to form water, and the carbon previoufly united to
this oxygen combined with the blood, and gave it a
deeper colour.

The venous blood of a fheep being expofed to nitrous
gas, immediately coagulated, and a great deal of blackifh
ferum feparated. The next day, on opening the bottle,
a very firong odour of nitric æther (dulcified fpirit of
nitre) was perceived, the nitrous gas having been in part
changed into nitric æther by the carbonated hydrogen of
the venous blood ; which proves that the venous blood
contains carbonated hydrogenous gas, which is eafily fe-

parated. The blood having loft this gas, had not re-
ceived it's vermilion colour; but, on the contrary, a
deeper colour. The deep colour of the venous blood is
not, therefore, owing to it's union with carbonated hy-
drogen, fince it becomes deeper after the feparation of
the hydrogen.

A fmall quantity of nitrous gas injected into the jugular
vein of a dog, killed it in lefs than fix minutes. The
blood in the right auricle and ventricle was black, thick,
and in part coagulated: that in the left was much more
deep than ufual.

2. *Arterial blood.*—Some arterial blood, from the caro-
tid artery of a fheep, was expofed to oxygen gas in the
fame way as the former experiments were made, and it
immediately received a more vermilion colour. The day
after, a very fmall quantity of carbonic acid gas was found
mixed with the oxygen gas.

Arterial blood immediately coagulated with azot gas,
and became of a very deep colour. The day after, a
fmall quantity of oxygen gas was found mixed with the
azot gas, fo that a candle burned in it nearly two minutes.
This experiment proves, 1. that arterial blood contains
oxygen gas: 2. that it's vermilion colour is owing to it's
union with this gas; and that, as foon as it is deprived of
it, it affumes it's deep colour again.

The blood expofed to carbonic acid gas received no
effect from it, although it has a great effect on venous
blood. Expofed to nitrous gas, it immediately coagu-
lated; and it's furface was green, and a little greenifh
ferum feparated. The day after, vapours of nitrous acid
were obferved on opening the bottle. This likewife
proves the prefence of oxygen in the blood, by it's con-
verting the nitrous gas into nitrous acid; the green was
owing to a fmall portion of azot, which feparated from
the nitrous acid. Expofed to hydrogen gas, it became

more vermilion-coloured, and remained fluid fome time before it coagulated, when a little ferum feparated. The next day a little oxygen gas was found with the hydrogen gas; this alfo, according to Girtanner, proves the prefence of oxygen gas in the arterial blood.

A fmall glafs tube filled with arterial blood, and fealed hermetically, was expofed to the light; it's colour changed by degrees; and, in fix days, it was as black as venous blood. This repeated, but expofed to heat inftead of light, the blood became black in a much lefs time. Thefe two laft experiments, firft made by Dr. Prieftley, appear to Girtanner to prove it is not to the contact of hydrogen gas that venous blood owes it's black colour. From thefe experiments Girtanner concludes that,

1. The change of colour in the blood, during circulation, is not owing to it's combination with hydrogen gas.

2. That the vermilion colour of arterial blood arifes from oxygen, with which the blood combines during it's paffage through the lungs.

3. That the deep colour of the venous blood is owing to the carbon it contains.

Haffenfratz.   Haffenfratz agrees pretty much with Girtanner. His opinion is, that the red colour of the blood proceeds from the folution of oxygen gas, and that it's brown and even black colour is occafioned by union of the hydrogen and carbon with the oxygen it holds in folution. He draws his conclufion from thefe facts. He firft ftates the two facts upon which all chemifts are of accord—1. that venous blood, mixed with oxygen, immediately receives a beautiful vermilion colour; that this red colour changes, by degrees, and becomes of a purple, like the ley of red wine, although the blood has been continually in contact with the oxygen, and both air and blood be conftantly fhaken together in order to unite them. 2. That arterial

blood, expofed to the action of every gas which does not
contain oxygen, receives a colour of the ley of wine.
From thefe he infers, that the red colour proceeds from
the folution of oxygen in the blood, and it's purple co-
lour from the oxygen abandoning the blood, and uniting
with it's hydrogen and carbon. The experiments Haf-
fenfratz made to convince himfelf of this are, he found
that oxygenated muriatic acid, when added to venous
blood, immediately decompofed it, and gave it a deep and
almoft black colour. He poured the fame quantity of
common muriatic acid into the quantity of blood, and the
blood was immediately decompofed, and flocks of a clear
brown were precipitated, that had not the black colour it
took with the oxygenated muriatic acid. Since the dif-
ference between the oxygen of the oxygenated muriatic
acid and oxygen gas is, that the firft is in a ftate fo as im-
mediately to combine on being put into contact with the
hydrogen and carbon of the blood, whilft the fecond is in
a ftate which renders the combination difficult, it follows,
that the colour the blood fuddenly takes with the oxyge-
nated muriatic acid, is that which blood ought to take,
in length of time, with oxygenous gas. Thus the black
colour of the blood is the refult of the intimate combina-
tion of the oxygenous gas with the carbon and hydrogen
of the blood, whilft it's red colour is only the refult of
the folution of oxygen gas in the blood. To affure him-
felf more pofitively of this truth, he repeated an experi-
ment of Girtanner : he filled feveral glafs tubes full of
blood made red by oxygen gas, and fealed them herme-
tically ; fome of which he put into the light, others into
the dark, and he found that the blood in all was become
blackifh, like the ley of wine. The reafon therefore of
the two phenomena which have excited the curiofity of
all philofophers, viz. the red colour of the blood in con-
tact with oxygen, and the brown colour when in contact

with the other gafes, arc eafily explained. As long as
the blood is in contact with oxygen, and this gas is dif-
folved in the blood, it is of a beautiful red ; but when it
is in contact with gafes that contain no oxygen, that
which is diffolved in the blood, and which occafions it's
vermilion colour, quits, by degrees, the whole mafs of
blood to combine partially with it's hydrogen and carbon,
and it's colour is brown ; and as the air in contact cannot
furnifh new oxygen, the colour continues to darken until
all the diffolved oxygen is combined. This chemift like-
wife explains the particular fact obferved by Fourcroy ;
the diminution of the high red colour of the blood, con-
ftantly in contact with hydrogen gas, by the diminution
of the force of attraction of the blood toward the oxy-
gen gas, in proportion as it's carbon and hydrogen are
combined with the gas of which it was firft in poffeffion ;
which affords a belief, that, fince the blood which circu-
lates has always the fame property of becoming red by
mixing with oxygen, although it has already taken a
confiderable quantity, during it's circulation it takes
from the fubftances with which it is in contact a quan-
tity of hydrogen and carbon, equal to that which fuccef-
fively combines with the oxygen. He then made fome
obfervations on the hypothefis of de la Grange. He
obferves, that fince the red colour of the blood is the con-
fequence of the folution of oxygen gas in it ; fince the
purple colour of the ley of wine, and even the dark
brown colour, proceed from the union of oxygen gas
with the carbon and hydrogen of the blood ; fince the ve-
nous blood is purple, and the arterial blood vermilion ; it
follows, that the arterial blood contains oxygen gas in
folution, that this oxygen unites itfelf by degrees with the
hydrogen and carbon of the blood during it's circulation,
and when the blood returns by the veins into the lungs all
the combination is made, and that it there diffolves again

oxygen gas, to return with a vermilion colour into the arteries. As the dark brown colour of the blood is in confequence of the union of oxygen with the carbon and hydrogen of the blood, and as the blood on paffing from the veins into the lungs to return back into the arteries becomes vermilion, it follows, that in the lungs very little union takes place between the carbon and hydrogen of the blood with the oxygen of the infpired air, and that the greateft combination is made during the circulation. It follows, therefore, on concluding, according to Haffenfratz, that,

1ft. The red colour of the blood is the refult of it's diffolving oxygen gas.

2d. That it's brown and even black colour arife from the combination of the hydrogen and carbon of the blood with the oxygen diffolved in it.

According to Davy, the arterial blood owes it's fine Davy. vermilion colour to light and oxygen, or the phofoxygen entering into it's compofition; and the venous blood is black, from a deficiency of phofoxygen, and a fuperabundance of carbon. Having defcribed the principal experiments and opinions of chemifts on the caufe of the difference of colour between venous and arterial blood, the third part of this article of refpiration will give an account of the different fyftems on animal heat.

Animal Heat. — The origin and caufes of heat in the Opinions animal body have been fubjects of difcuffion from the of it. earlieft ages; but the ignorance of the ancients in fcience, and their fuperftition, which is always the confequence of it, enabled them only to form extravagant and abfurd ideas. It is well known how greatly they were inclined to attribute every thing they could not underftand to fupernatural power, and this propenfity pervaded the wifeft. We are told that even the great father of medicine, Hip- Hippo- pocrates, was not devoid of this weaknefs. He confidered crates. heat as a myftery, and even beftowed upon it feveral of

the attributes of the Deity. "What we call heat," says he, "appears to be something immortal." We

Galen.

learn from Galen that the hypothesis amongst some physicians in his time was, that animal heat depended on the motion of the heart and arteries; and as they looked upon this motion to be innate, they considered that heat was likewise so : this hypothesis however he rejects ; and, being a peripatetic philosopher, he accounts for it according to that system.

Amongst the moderns, different authors have amused themselves and the world by inventing many fanciful

Helmont.

theories on this subject. Thus Van Helmont and Sylvius attributed animal heat to the effervescence which they thought took place in the intestinal canal from the mixture of the pancreatic juice and the bile. This notion appears to have originated from having observed that a degree of heat was produced from the mixture of certain bodies, which sometimes amounted to actual inflammation. Others attributed it to the same cause ; but disagreed as to the place where this mixture happened, and of the nature of the fluids of which it consisted.

Accounted for by mixture.

Another opinion, which continued nearly two centuries, was that of the mixture of acids and alkalis ; it was imagined that acescent fluids, when taken into the stomach, met with others of an alkaline nature already prepared ; and this gave rise to the heat peculiar to the animal body.

After the absurdity of explaining the phenomena of the human machine by chemical mixture had been perceived by physiologists, it was succeeded by fermentation. It

Fermentation.

had been observed that fermentation was productive of heat, and as it was the fashion to explain the phenomena which took place in the vital functions by fermentation, they thought they could not do better than to attribute animal heat to the same cause ; and although some of them modified their conjecture respecting the peculiar species of

fermentation, it was chiefly confined at laft to the putre-
factive, more efpecially as it was fuppofed that procefs
took place during digeftion   Soon after the immortal
Harvey had explained the circulation of the blood, the
mechanical generation of animal heat took it's rife ; and Mechanical
fo certain were phyfiologifts of it's truth, that they looked means.
upon it almoft as capable of mathematical demonftration.
They firft conceived this opinion from obferving that ani-
mal heat generally keeps pace with the ftate of the circu-
lation ; that when the heart and arteries beat high and
quick, a great degree of heat is produced : on the con-
trary, when their action becomes more faint and languid,
the animal heat is likewife diminifhed. There was, how-
ever, one point in which the mechanical phyfiologifts
could not agree, _i. e._ whether it were occafioned by the
attrition of the blood againft the veffels which contain it,
or by the internal agitation and friction of the particles
againft each other.   Hence it gave rife to various con-
jectures : many ingenious arguments were brought in
fupport of each hypothefis ; but, as facts could not de-
termine the point, it fell, as moft other hypothefes do,
for want of proper evidence.

According to Dr. Mortimer, animal heat arifes from Opinion of
the phofphorus and air which the animal fluids contain. Dr. Morti-
He thinks thefe lie in a dormant ftate until brought into
contact, which is effected by means of the circulation ;
and if it were not for the abundance of aqueous humours
in animals, he alleges that incenfions would frequently
happen.

According to Douglas, animal heat arifes from the According
friction of the globules in their circulation through the to Douglas.
capillary veffels. Stevenfon fays that it is owing to the
fame procefs by which our aliment and fluids are perpe-
tually made to undergo fome alteration. According to
Franklin, the fluid fire, as well as the fluid air, being at-

tracted by plants in their growth, and consolidated with
the other materials of which they are composed, after
being digested, and having undergone a kind of fermen-
tation in the vessels, part of the fire and air recovers it's
fluid active state again, and diffuses itself over the body,
which is the animal heat.

A more accurate and extensive knowledge of the human
œconomy soon saw into the futility of such methods of
argument, and a more ingenious hypothesis perhaps than
Cullen.   had hitherto appeared was attempted by Dr. Cullen,
which he delivered in the form of little more than a con-
jecture. He was of opinion that the difference of tempe-
rature in different animals is owing to a difference in
the vital principle; so that, although the velocity of the
blood may be the same in a frog as in a man, yet, in
consequence of the variety in the vital principle, the heat
produced may be different; hence he supposes the princi-
ple of life has the power of generating heat or cold.

The doc-   The phlogiston of Stahl now came more into fashion,
trine of
Stahl in   and served to explain the origin of animal heat. Dr.
fashion.   Black having observed that animals which respire are of
Opinion of
Black.   all others the warmest, and that there exists a striking
and close connexion between their state of respiration and
their degree of heat, was induced to conclude that animal
heat is generated in the lungs by the action of the air
on the phlogiston or principle of inflammability, in a
manner not dissimilar to what he supposed to take
place in actual inflammation, and that it is diffused by
the circulation over the rest of the system. This opi-
nion was defended by many arguments.—1. It was said,
that since a quantity of mephitic phlogisticated air is
known constantly to exhale from the lungs, and that at-
mospheric air, by passing through the lungs, acquires the
same properties as by passing through fuel in actual in-
flammation, or by being exposed to any other process of

phlogiſtication, it is obvious that the change the common air undergoes in both caſes ought to be attributed to one and the ſame cauſe, viz. it's combination with phlogiſton. 2. This hypotheſis has been ſupported by urging, that the celerity with which the principle of inflammability is ſeparated in reſpiration, is very cloſely connected with the degree of heat peculiar to each animal. Thus man, birds, and quadrupeds, vitiate air very faſt; ſerpents and all the amphibious ſpecies, very ſlowly; and the latter are of an inferior temperature to the former, and breathe leſs frequently. 3. The moſt ingenious and cogent argument which the defenders of this theory have uſed is, that no heat is generated till the function of reſpiration takes place; for the fœtus in utero derives all it's heat from the mother.

Againſt this theory, Dr. Leſlie brings the following ob- *Oppoſed by* jections. 1ſt. That there are various proofs of the im- *Dr. Leſlie.* poſſibility of the lungs being the ſource or elaboratory of animal heat, ſince animals without organs of reſpiration generate heat, and even thoſe fiſhes which are deſtitute of gills appear, from various experiments, to be warmer than the ordinary temperature in which they live: hence reſpiration is not abſolutely neceſſary for the production of animal heat. 2. If animal heat be generated ſolely in the lungs, it can only be communicated to the reſt of the body by the arterial ſyſtem, and the heat muſt decreaſe as it recedes from it's ſuppoſed centre. But it is more conformable to facts, that the venous blood is, if not warmer, at leaſt as warm as the arterial; and according to Dr. Stevenſon the thermometer immerſed in flowing venous blood riſes ſeveral degrees higher than that placed in the arterial, whilſt there is no experiment to ſhow the temperature of the blood to be higher in the left ventricle than in the right; which would be the caſe if all the animal heat was generated in the lungs. 3. Having thus

rendered it improbable that the generation of animal heat
should be entirely confined to the lungs, Dr. Leslie en-
deavours to show that the vital fluid, far from acquiring
all it's heat in the pulmonary syftem, communicates no
inconfiderable portion of what it has received in the courfe
of circulation to the air, alternately entering and issuing
from that organ. Were the blood heated in the lungs,
their function would be lefs neceffary in a warm than in
a cold atmofphere: but it is known that when the air is
extremely hot a perfon breathes full and quick to become
cool, and in intenfe cold refpiration is flow and languid;
which would not be the cafe if the blood was heated in
the lungs by the action of the air upon it. The air ap-
pears rather to diminish than increafe the animal heat by
carrying off phlogifton from the lungs: hence Dr. Duncan
compared refpiration to the blowing of bellows on a hot
body; in both cafes a confiderable degree of heat is com-
Opinion of municated to the air. Dr. Leslie having thus brought his
Dr. Leslie. arguments againft the theory of Dr. Black, and after
showing that heat, though *generated*, cannot accumulate
in the foetus, erects another theory in it's place, which
depends upon the following pofitions:

1. That the blood contains phlogifton.

2. That this phlogifton is evolved, extricated, or
brought into a ftate of activity and motion, by the action
of the blood-veffels to which it is fubjected in the courfe
of circulation.

3. That the evolution of phlogifton is a caufe which
throughout nature produces heat; whether that heat be
apparently excited by mixture, fermentation, percuffion,
friction, inflammation, ignition, or any fimilar caufe.

4. That this heat, produced in confequence of the
evolution of phlogifton from the blood of different animals,
is in all probability equal to the higheft degree of heat
thefe animals in any cafe poffefs. To this theory of

Dr. Leslie·succeeded that of Dr. Adair Crawford, who proved the fundamental principle Leslie laid down, viz. that the venous blood is warmer than the arterial, to be false. He likewise appears to be the first who attempted to afcertain, by direct experiment, the cause of animal heat.

Dr. Crawford, who in his general doctrine of heat Theory of seems to agree with Dr. Irwin of Glasgow, begins with Crawford. an explanation of his terms. The words *heat* and *fire* he tells us are ambiguous. *Heat* in common language Heat. has a double fignification : it is used indiscriminately to exprefs a fenfation of the mind, and an unknown principle, whether we call it a *quality* or a *fubftance*, which is the exifting caufe of that fenfation. The latter, with Dr. Irwin, he calls *abfolute heat*, the other *relative heat*. It therefore appears that *abfolute heat* expreffes in the abf- Abfolute. tract that *power* or *element*, which, when it is prefent to a certain degree, excites in all animals the fenfation of heat ; and *relative heat* expreffes the fame power, confi- Relative. dered as having a relation to the effects by which it is known and meafured ; for inftance, fuch as the effect it produces upon an inftrument called a thermometer, employed in meafuring it. It has been found by experiment, that in bodies of different kinds the quantities of abfolute heat may be unequal, though the temperatures and weights, or their relative heat be the fame. Thus, if a pound of water and a pound of diaphoretic antimony have a common temperature, the quantity of abfolute heat contained in the former is nearly four times that contained in the latter. When the principle of heat is confidered relatively to the whole quantity of it contained in bodies of different kinds, but which have equal weights and temperatures, it is termed *comparative* heat. If, for example, the tem- Compara- peratures and weights being the fame, the whole quantity tive. of heat in water be four times as great as that in an-

timony, the comparative heats of thefe fubftances are faid to be to each other as four to one. The comparative heats of bodies of equal weights and temperatures are greater or lefs in proportion, as lefs or greater alterations are produced in their temperatures by equal quantities of abfolute heat. Thus, the fame quantity of heat which raifes a pound of water one degree is fufficient to raife a pound of mercury 28 degrees : hence the comparative heat of water is to that of mercury as 28 to 1. As equal weights of heterogeneous fubftances are found to contain unequal quantities of abfolute heat, there muft be certain effential differences in the nature of bodies, from which *fome* have the power of collecting and retaining that element in greater quantity than others. Thefe dif-

Capacities of bodies for containing heat.

ferent powers are called the *capacities* of bodies for containing heat : thus, if a pound of water contains four times as much abfolute heat as a pound of diaphoretic antimony at the fame temperature, the capacity of water for containing heat is to that of antimony as four to one. Such are the principal definitions Dr. Crawford has laid down. He then gives fome general facts refpecting heat, and afterward begins to examine animal fubftances, fo as to produce a theory upon animal heat.

Arterial blood contains more heat than water.

On making experiments with animal fubftances refpecting their comparative heats, he found that arterial blood contained a greater quantity of abfolute heat than water, which compofed fo large a portion of it; for, taking water as a ftandard at 1.000, arterial blood was 1.03. The remarkable accumulation of heat in this laft fluid led Dr. Crawford to fufpect it abforbs heat from the air in the procefs of refpiration ; and he was much confirmed in his fufpicion by the following confiderations :

Confiderations in confequence.

1. Thofe animals furnifhed with lungs, and which continually infpire frefh air in large quantities, have a tem-

perature confiderably higher than the furrounding atmo-
fphere, whilft animals without refpiratory organs are
nearly of the fame temperature with the medium in which
they live.

2. Among hot animals, thofe are warmeft which have
the largeft refpiratory organs, and which confequently
breathe the greateft quantity of air in proportion to their
bulk, fuch as birds.

3. The degree of heat in the fame animal is in fome
meafure proportionable to the quantity of air infpired in
a given time : thus the animal heat is increafed by exer-
cife, or whatever accelerates refpiration.

From thefe he was led to examine the fubject of ani- *Propofi-
mal heat more particularly, the refult of which is com- *tions from a
prehended in the following propofitions : *particular
*examina-
*tion of ani-
1. The quantity of abfolute heat contained in pure *mal heat.
air is diminifhed by the change it undergoes in the lungs
of animals, and the quantity of heat in any kind of air fit
for refpiration is nearly proportional to it's power in fup-
porting animal life.

2. The blood which paffes from the lungs to the heart
by the pulmonary vein contains more abfolute heat than
that which paffes from the heart to the lungs by the pul-
monary artery.

3. The comparative quantities of heat in bodies fup-
pofed to contain phlogifton are increafed by the changes
they undergo in the proceffes of calcination and combuftion.

4. The colour of the venous blood of a living ani-
mal approaches more nearly to that of the arterial in a
warm than in a cold medium ; lefs air is phlogifticated,
in a given time, in the former than in the latter fituation;
and the heat produced by the refpiration of an animal is
nearly equal to that produced by the burning of wax or
charcoal, the quantities of pure air confumed being the
fame.

G 4

Explanation
of animal
heat from
Dr. Craw-
ford's ex-
periments.

Dr. Crawford, from experiments made on the compa-
rative heats of different airs and animal fubſtances, ſo as to
explain the phenomena of reſpiration and animal heat, found
that water being the ſtandard at 1.000, inflammable air was
21.4000; dephlogiſticated air 4.7400; atmoſpherical air
1.7900; aqueous vapour 1.5500; fixed air 1.0400; phlo-
giſticated air 0.7936; arterial blood 1.0400; venous
blood 0.8928; freſh milk of the cow 0.9990; hide of an
ox with the hair 0.7870; lungs of a ſheep 0.7690; lean of
the beef of an ox 0.7400:—he therefore forms an eſti-
mate of the quantity of heat yielded by the purer part of
atmoſpherical air when it is converted into fixed air and
aqueous vapour during reſpiration, and alſo of that which
is abſorbed during the converſion of venous into arterial
blood by the ſame proceſs, explaining his theory of ani-
mal heat in the following manner.

From having proved that the comparative heat of pure
air is to that of the fixed air and aqueous vapour, into
which it is changed in the lungs, as three to one, the
ſame heat which raiſes the pure air one degree will raiſe
the fixed air and aqueous vapour three degrees; and, con-
ſequently, the ſame heat which raiſes pure air any given
number of degrees will raiſe the fixed air and aqueous
vapour the ſame number of degrees multiplied by three.

Having proved that pure air at the common tempera-
ture of the atmoſphere contains 1550 degrees of heat, if a
certain quantity of pure air, not in contact with any body
that would immediately carry off the heat, ſhould ſuddenly
be converted into fixed air and aqueous vapour, the heat
contained in the former would raiſe the latter 1550 de-
grees multiplied by three, or 4650 degrees; and the tem-
perature of red hot iron being 1050, it follows that the
quantity of heat yielded by pure air, when converted into
fixed air and aqueous vapour, is ſuch (if it were not diſſi-
pated) as would raiſe the air and vapour ſo changed to

more than four times the excefs of the heat of red-hot iron above the common temperature of the atmofphere. If, therefore, the abfolute heat which is difengaged from the air in refpiration were not abforbed by the blood, a very great degree of fenfible heat would be produced in the lungs.

Again, having proved that the fame heat which raifes venous blood 115 degrees will raife arterial only 100 degrees; the fame heat which raifes venous blood any given number of degrees will raife arterial a lefs number, in the proportion of 100 to 115, or of 20 to 23. But venous blood contains at leaft 1580 degrees of heat : hence, if a certain quantity of venous blood, not in contact with any body that would immediately fupply it with heat, fhould fuddenly be converted into arterial, the heat contained in the former would raife the latter only $\frac{20}{23}$ of 1580 degrees, or 1373 degrees ; and confequently the fenfible heat would fuffer a diminution equal to the difference between 1580 and 1373, or nearly 200 degrees. But the common temperature of the blood is 96 : when therefore venous blood is converted into arterial in the lungs, if it were not fupplied by the air with a quantity of heat proportionable to the change it undergoes, it's fenfible heat would be diminifhed 200 degrees, or it would fall from 96 to 104 below the zero of Fahrenheit.

That animal heat depends upon the feparation of elementary fire from the air in the lungs is likewife, according to Dr. Crawford, fupported by experiments made in fupport of the third and fourth propofitions. For from thofe of the third it appears, that when bodies are united with the inflammable principle they part with a portion of their elementary fire ; and when this is again difengaged, they reabforb an equal portion of this fire from the furrounding bodies. It alfo appears, from thofe of the fourth propofition compared with the difcoveries of

Priestley and Cavendish, that when pure air is combined
with the inflammable principle, in the state of light in-
flammable air, it is changed into aqueous vapour; but in
the state of heavy inflammable air it is converted into
fixed air; that wax, oil, and tallow consist chiefly of
heavy and light inflammable air in a solid state; that,
when pure air is altered by the combustion of these sub-
stances, fixed air and aqueous vapour are produced, and
the same products are obtained when that fluid is altered
by the respiration of an animal. Hence it follows, that
in respiration and combustion the pure air is altered in
it's properties by combining with the inflammable prin-
ciple: and since we know that the union of these ele-
ments is universally accompanied with the extrication of
heat, and a large quantity of elementary fire is disen-
gaged from the air in the combustion of oleaginous sub-
stances in particular, it may be concluded, that in the
process of respiration a similar extrication of fire takes
place; and this is confirmed by some experiments, the
results of which are, that when equal quantities of air are
changed by the respiration of an animal, and by the com-
bustion of a wax taper, the quantities of sensible heat
produced are nearly the same.

It has also been proved, that the change the blood un-
dergoes during it's circulation in the lungs is similar to
that which solid bodies undergo when melted; i. e. their
capacities are increased: and since when solid bodies are
melted a quantity of heat is absorbed, it may be conclud-
ed, that when venous is changed into arterial blood a si-
milar absorption takes place.

Lastly, experiments show, that when an animal is
placed in a cold medium, the venous blood acquires a
deeper hue, and a greater quantity of air is altered by re-
spiration in a given time than when it is in a warm me-
dium. Now, Dr. Priestley has proved that the livid
colour of the venous blood depends upon it's union with

the inflammable principle: hence, the more the blood contains, the more it phlogisticates the air in the lungs in a given time, and a greater quantity of elementary fire is abforbed, in proportion as the animal is in a medium of a low temperature. Hence, the quantity of heat feparated from the air, and abforbed by the blood, is in all cafes proportioned to the neceffity: the elementary fire is therefore the true caufe of animal heat.

Animal heat, therefore, depends upon a procefs refem- *Source of animal heat, and the procefs of it's production.* bling a chemical elective attraction. The pure air is received into the lungs containing a great quantity of elementary fire; the blood is returned from the extremities impregnated with the inflammable principle; the attraction of pure air to the latter principle is greater than that of the blood. This principle will therefore leave the blood to combine with the air: by this combination the air is obliged to depofit a part of it's elementary fire; and as the capacity of the blood is at the fame moment increafed, it will inftantly abforb that portion of fire detached from the air. The arterial blood, in it's paffage through the capillary veffels, is again impregnated with the inflammable principle; hence it's capacity for heat is diminifhed, as is fhown by experiments in proof of the fecond propofition. It will therefore, in the courfe of circulation, gradually give out the heat it received in the lungs, and diffufe it over the whole fyftem. Thus, in refpiration, the blood is continually difcharging the inflammable principle and abforbing heat, and in circulation continually imbibing this principle and emitting heat. But as heat is not proved to be a fubftance, Dr. Crawford does not mean to fay that elementary fire is capable of chemical combination; or to affirm that heat is difengaged from the air in refpiration by means of a double elective attraction: he only gives conclufions deduced from facts and experimental teftimony; and if it be ad-

mitted as a certain truth, that a *diminution* is produced in the quantity of heat contained in the air, and an *increase* in it contained in the blood, by respiration, it will not be denied that, in this process, heat is continually passing from the air to the blood.

To this may be added, that as the blood by it's impregnation with the inflammable principle has it's capacity for heat diminished, so, on the contrary, those parts of the system from which it receives this principle will have their capacity for heat increased, and will consequently absorb heat.

The capacities of those parts which give out the inflammable principle are not however so changed as to absorb all the elementary fire during circulation; for then it would be necessary to have recourse to some other cause to account for the sensible heat produced in the circulation : hence, a part of the fire separated becomes redundant. This is likewise supported by an extensive analogy; for the process by which the arterial blood is phlogisticated during it's passage through the minute vessels is similar to that by which pure air is phlogisticated in the combustion of oleaginous substances. In the latter process, the inflammable principle is separated from an earthy basis, and combined with the air; in the former, it is separated from the putrescent parts of the system, and combined with the blood. In both cases, the capacity of the body which parts with it is increased, and that of the body which receives it, diminished; and since in combustion a quantity of heat becomes redundant, the conclusion is, that the same happens in circulation. It must, however, be granted, that those parts of the system which communicate the inflammable principle to the blood have their capacity increased, and therefore a part of the fire separated from the blood will be absorbed; and to this cause is perhaps owing, that less heat is produced by an animal than by the burning of a wax taper, the quantities of air

Arterial blood phlogisticated in the same way as pure air in combustion.

confumed being equal; for, probably, the putrefcent juices as foon as they have given the inflammable principle to the blood fly off in the form of infenfible perfpiration, carrying a part of the fire detached in circulation : the portion of fire thus abforbed, however, is not very confiderable, as appears from the quantity of heat which becomes fenfible in the animal body. It therefore appears, that the blood in it's progrefs through the fyftem gives out the elementary fire it had received in the lungs from the air, a fmall portion of which fire is abforbed by thofe particles which impart the principle to the blood, and the reft becomes redundant, or is converted into moving and fenfible heat.

Part of the fire redundant.

Dr. Crawford then recites the principal facts relating to animal heat in the following manner :

Principal facts relating to animal heat.

1. He is of opinion, that the doctrine juft ftated explains the reafon why breathing animals have a higher temperature than thofe which are not furnifhed with refpiratory organs ; for it has been proved, that the former are continually abforbing heat from the air ; and it is probable, that to provide an apparatus for the abforption of heat, was the chief purpofe of nature in giving to fo great a part of the animal creation a pulmonary fyftem, and a double circulation. The quantity of air changed by a man in a minute is found by experiment to be equal to that altered by a candle in the fame fpace of time ; and hence a man is continually deriving as much heat from the air as is produced by the burning of a candle. Naturalifts have remarked, that the cold animals have alfo the power of keeping themfelves at a temperature fomewhat higher than the furrounding medium. It is probable that in thefe animals the aliment contains more abfolute heat than the blood ; for, as the blood during it's paffage through the capillary veffels has it's capacity diminifhed, and hence is obliged to give out a part of it's

Animals with refpiratory organs have a higher temperature that others which have not

absolute heat, the source from which it is again supplied, these animals having no lungs, and consequently a want of respiration, is perhaps the aliment.

2. From the experiments of Dr. Fordyce made in heated rooms, it appears that the animal body has, in certain situations, the power of producing cold, or of keeping itself at a lower temperature than the surrounding medium. This could not arise solely from evaporation from the surface, as some have supposed, as the Doctor remained in moist air heated to 130 for 15 minutes, when the thermometer stood at 100 under his tongue, and streams of moisture ran from his whole body, from the condensation of vapour, as appears from a similar condensation on the surface of a Florentine flask filled with water at 100. He found a dog could live without much inconvenience a considerable time in air at 260, the body of the animal being never raised more than two degrees above the natural standard. That this generation of cold does not arise solely from evaporation, appears from some experiments made by Dr. Crawford upon living and dead frogs. A living and dead frog, equally moist and nearly of the same bulk, the former being at 67, the latter at 68, were laid upon flannel in air raised to 106. Two sensible thermometers were placed in contact with the skin under the axillæ, and the order of cooling was observed for 25 minutes.

Minutes.	Air.	Dead Frog.	Living Frog.
In 1	———	$70\frac{1}{2}$	$67\frac{1}{2}$
2	102	72	68
3	100	$72\frac{1}{2}$	$69\frac{1}{2}$
4	100	$72\frac{1}{2}$	$69\frac{1}{2}$
25	95	$81\frac{1}{4}$	$78\frac{1}{2}$

The thermometers being introduced into the stomach, the internal heat was found to be the same with that at the surface. Hence the living frog acquired heat more slowly than the dead one. A living and dead frog were

taken at 75, and immerfed in water at 93, the living frog
being placed in fuch a fituation as not to interrupt refpi-
ration.

	Minute.	Dead Frog.	Living Frog.
In	1	85	81
	2	$88\frac{1}{2}$	85
	3	$90\frac{1}{2}$	87
	5	$91\frac{1}{2}$	89
	6	$91\frac{1}{2}$	89
	8	$91\frac{1}{2}$	89

Since therefore living frogs have the power of pro-
ducing cold in warm water, as well as in warm air; and
fince the human body has the fame power in a moift as
well as in a dry air; we may conclude that this power
does not folely depend upon evaporation. Dr. Crawford
therefore explains it as follows :—It appears from experi-
ment that the capacity of the blood for containing heat is
fo much increafed in the lungs, that if it's temperature
were not fupported by the heat feparated from the air in
refpiration, or the parts adjacent, it would fink 200 de-
grees. Hence, if evaporation from the lungs be fo much
increafed as to carry off all the heat detached from the air,
the arterial blood, when it returns by the pulmonary vein,
will have it's fenfible heat greatly diminifhed, and will
confequently abforb heat from the veffels in contact with
it and the neighbouring parts. The heat thus abforbed
in the greater veffels will again be extricated in the ca-
pillaries, where the blood receives a frefh addition of the
inflammable principle. If in this cafe the blood, during
each revolution, were to be equally impregnated with it,
the whole effect of the above procefs would be to cool
the fyftem at the centre, and convey the heat to that part
of the body where it can be inftantly carried off by eva-
poration. But it appears that, when an animal is placed in
a heated medium, the blood is lefs impregnated ; for the

venous blood in this cafe becomes gradually paler and
paler, till it is nearly like arterial; and it is proved by
Dr. Priestley, that the livid colour depends upon combin-
ing with the inflammable principle in the minute vessels.
Since, therefore, in a heated medium, it does not assume
the same livid hue, we may conclude it does not take in
an equal quantity of the phlogistic principle; and this
conclusion is confirmed by experiments, which prove that
the quantity of air an animal phlogisticates, in a given
time, in a warm medium, is less than in a cold medium.
It follows, from these facts, that the quantity of heat
given by the blood in the capillaries will not equal what it
had absorbed in the greater vessels, or positive cold will be
produced.   For example :—If the blood in passing to the
capillaries absorb from the greater vessels a quantity of
heat as 200, and if, from not receiving a less impregnation
of the phlogistic principle than formerly, it give off at the
extreme vessels a quantity of heat only as 150, a degree
of refrigeration will be produced as 50; and this refrigera-
ting cause will continue to act while the colour of the
venous is approaching the arterial, till it comes the nearest
possible; after which it will cease to operate.   Thus, when
animals are placed in a warm medium, the same process
which formerly supplied them with heat becomes for a
time the instrument of producing cold, and probably pre-
serves them from such rapid alterations of temperature as
might prove fatal to life.   Upon the whole, the increased
evaporation from the surface, and the diminution of that
power by which the blood in it's natural state is im-
pregnated with the phlogistic principle, seem to be the
great causes on which the refrigeration depends.   By the
first the animal is cooler at the surface, and by the second
an accumulation of heat at the centre is obviated.

The power which animals possess of cooling themselves
at the centre, when placed in a medium above their natu-

ral heat, seems peculiarly necessary to preserve life. For, as the heat received at the surface is speedily, in such cases, carried towards the internal parts by the reflux of the heated fluids, if it were not absorbed and rendered insensible by the change of the blood in the lungs, the central heat would probably soon be so increased as to destroy the vital principle.

3. The reason is now evident why animals preserve an equal temperature during the great variations of the heat of the atmosphere, arising from the changes of weather and difference of season and climate. The equal temperatures of animals.

From experiments in proof of the fourth proposition it appears, that in respiration the difference between the purity of the inhaled and expired air is increased by exposing the animal to cold; and likewise the difference between the colour of the arterial and venous blood is augmented from the same cause. But the quantity of fire separated from the air must be in proportion to these differences. For, as the extrication of heat from that element is produced by it's phlogistication, the more completely a given portion of air is phlogisticated, the greater will be the quantity of heat detached from it. The same with respect to the phlogistication of the blood. It follows, as soon as by exposure to cold an unusual dissipation of the vital heat is produced, the blood will begin to be more deeply phlogisticated; hence will give more of it to the air, and in return get a greater portion of fire. In summer the reverse will take place; the air will be less tainted by respiration, a smaller portion of the phlogistic principle will be attracted by the blood, and the quantity of fire absorbed will be proportionably diminished. Hence the heating and cooling powers in the animal body are so adjusted to each other, as to produce an equal effect; and consequently the law by which animals maintain an uniform temperature is similar to that by which the temperatures of bodies

become fixed when they have arrived at the melting or freezing points. When freezing water, for example, is expofed to a cold atmofphere, the quantity of elementary fire carried off by the furrounding air is precifely balanced by what is extricated from the water at the moment of congelation. In like manner, when an animal is expofed to a cold atmofphere, the quantity of heat carried off by the circumambient medium is balanced by what is detached from the blood in circulation. On the contrary, when ice is placed in a warm atmofphere, the whole of the heat it receives is rendered infenfible; and it has been fhown, that when an animal is placed in a warm medium, a fimilar extinction of the heat takes place.

Hence the power animals poffefs of generating heat is in all cafes proportioned to the demand. It is increafed by the winter colds, diminifhed by the fummer heats, and is totally fufpended, or converted into a contrary power, as the exigencies of the animal may require.

As the quantity of air an animal phlogifticates in a warm medium is not fo great as in a cold one, it follows, that in countries between the tropics the air will be lefs contaminated, ceteris paribus, by the refpiration of animals than in the temperate and frigid zones; and the difference is confiderable, if we recollect that the phlogiftication of a given quantity of air by an animal at the temperature of 50, was found to be twice as great as that produced by the fame animal in an equal time at 100. In thofe parts of the earth, therefore, in which the contamination of the air is increafed by the influence of heat upon *dead* animal fubftances, that element fuftains lefs injury from the refpiration of *living* animals.

An animal is hot in proportion to the air he breathes in a given time.

4. Among different animals, thofe are the hotteft which breathe the greateft quantity of air in proportion to their bulk; and in the fame animal the degree of heat is in fome meafure proportionable to the quantity of air inhaled

in a given time. Hence in exercise, by the action of the
muscles, the venous blood is returned from the extre-
mities, in greater quantities than usual, to the right auri-
cle of the heart. By the action of the heart it is deter-
mined to the lungs. The respiration is accelerated, the
velocity of circulation increased, and hence a proportion-
able increase in the quantity of heat absorbed. The cold
stage of fevers is preceded by languor, and a diminution
in the action of the heart and arteries. The respiration is
small, the quantity of blood which passes through the
lungs in a given time is diminished; and hence less phlo-
giston will be discharged from the blood, and consequently
less heat separated from the air. In putrid fevers, as the
solid and fluid parts of the system are in a putrescent state,
and consequently retain the principle of inflammability
with less force, a greater quantity of this principle will
be discharged from the lungs, the air will be more copi-
ously supplied with it in the process of respiration, and
will, therefore, impart to the blood a greater proportion
of it's absolute heat. To these causes it is probably owing,
that the heat of the human body never rises so high as in
putrid fevers.

5. Topical inflammation is accompanied with redness, The in-
tumour, and unusual heat. From the throbbing of the crease of
heat in
vessels, and from microscopical observations, it appears topical in-
flammation.
that the velocity of the blood through the part inflamed is
accelerated. Hence the blood is more copiously supplied
with phlogiston, and a greater quantity of heat will there-
fore be extricated in a given time. This heat will stimu-
late the vessels into more frequent and forcible contrac-
tions, by which the velocity of the blood, and the conse-
quent extrication of heat, will be still further increased.
It is on this principle that, according to Dr. Crawford, we
may perhaps account for the partial heats produced by
topical inflammations, and for those in hectic and nervous

diseases.   Heat in topical inflammations is accumulated
by the increased velocity of the blood through the part
inflamed, in the same manner as it is accumulated upon
the fuel in combustion by directing a stream of fresh air
into the fire.

Mayow has already been considered as the first amongst
the modern philosophers, who showed the cause of
combustion and respiration to be the same.   It however
appears that several had preceded him, if not in experi-
ment, at least in conjecture.   Something was supposed to
exist in the air, equally necessary to respiration and com-
bustion, so early as the beginning of the seventeenth cen-
cury.   Pegelius, in a book entitled Thesaurus Rerum
selectarum, magnarum, dignarum, utilium, suavium, pro
Generis humani Salute oblatus, Auct. Magno Pegelio,
1604, says, " quod *aer respiratione attractus*, corpus to-
" tum subintret, et motum continue cum vita restituat
" et sustentet, et illud quod hinc continue exterius de-
" fluit et quod per os iterum ex interioribus seu ex toto
" egreditur, restituat et subimpleat; non secus quam *ignis*
" *ex aere attracto* et corpora excalefacta et ardentia pene-
" trante subinde generatur et sic alitur."   We are inform-
ed by Dr. Thornton that Hooke, in his Micrographia
printed in Nov. 1664, had made some discoveries relative
to the use of air in combustion and respiration, by which
he preceded Mayow nearly four years ; " the air being
" a subject," says Hooke, " which (although all the
" world has hitherto lived and breathed in, and been con-
" versant about) has yet been so little explained, that a
" diligent inquirer will be able to find but very little in-
" formation from what has been (till of late) written upon
" it : but being once well understood, it will, I doubt not,
" enable a man to render an intelligible, nay, probable,
" if not the true reason of all the *phenomena of fire*,
" which, as it has been found by writers and philosophers

" of all ages, a matter of no small difficulty, as may be
" sufficiently understood by their strange hypotheses and
" unintelligible solutions of some few phenomena of it ;
" so will it prove a matter of no small concern and use in
" human affairs, when I come to show the use of *air in*
" *respiration*, and for the preservation of the life ; nay,
" for the conservation and restoration of the health and
" natural constitution of mankind, as well as all other
" aërial animals; as also the uses of this principle or
" property of the air in chymical, mechanical, and other
" operations."

A third instance of the process of respiration having
been compared to combustion, is in the collection of
Wedel, published at Jena in 1686; the title is, " G. W.
Wedel Exercitat. Med. Physiol. &c. Jena, 1686," in which
is a dissertation, " Von der thierischen Wærme, Nutzen
des Athemholers, &c. ;" and finally, this resemblance
was observed by Dr. Black.

It appears, therefore, that the similarity between com-
bustion and respiration, or that the principle was the same
that was consumed in both, had already been noticed, al-
though in a vague manner ; but the properties and nature
of this cause, which exists in the atmosphere, had escaped
their observation ; and hence the most necessary part of
the function of respiration was unknown ; for, before any
real light could be thrown upon this obscure subject,
several facts were necessary to be acknowledged.

1st. That caloric (matter of heat) is a constituent part
of fluids, and that it is to this principle they owe their
expansibility, their elasticity, and several other properties
we know they possess.

2d. That the atmospheric air is composed of two aëri-
form fluids, *i. e.* of about one fourth part of vital air,
and three fourths of azot gas.

3d. That the basis of vital air, oxygen, is a principle

common to all acids, and that it is this which conftitutes their acidity.

4th. That carbonic acid gas (fixed air) is the refult of the combination of about 72 parts in weight of oxygen, and of 28 parts of carbon (pure charcoal).

5th. That lefs caloric enters into the compofition of a given volume of carbonic acid gas, than of an equal volume of vital air; and that it is on this account that caloric is difengaged during the combuftion of carbon, *i. e.* during the converfion of vital air into carbonic acid gas by the addition of carbon.

6th. Laftly, that water is not an element, nor a fimple fubftance, as the ancients fuppofed, but that it is compofed of 14.338 parts of oxygen, and of 85.668 parts of hydrogen.

Thefe facts being eftablifhed, a great deal was done in the explication of the production of animal heat.

From the fuppofition of the Stahlians, air was phlogifticated by refpiration as well as by combuftion; but Lavoifier announced in 1777, in a memoir read to the Academy, that refpiration was a flow combuftion of a portion of carbon which the blood contains, and that animal heat is caufed by a portion of the caloric that is difengaged at the moment of the converfion of the vital air of the atmofphere into carbonic acid gas, as happens in the combuftion of charcoal; but he offered it only as a very probable conjecture: whilft Crawford, who had difcovered the caufe of it nearly at the fame time as Lavoifier, and in the fame year, publifhed his very interefting work in 1779, in which he collected a number of experiments to realize this fufpicion. In 1788 a very enlarged edition of this work appeared, from which the account given of his doctrine is taken, and from which it feems that Dr. Crawford ably fupports the phlogiftic fyftem.

The experiments which Lavoifier and de la Place

publifhed in 1780 confirm the opinion the firft chemift had conceived, and totally overturned the theory of phlogifton. To determine the effects of refpiration and combuftion upon air, thefe two chemifts introduced a guinea-pig under a glafs veffel containing 248.01 inches of pure air, and let it remain there an hour and a quarter. After having taken away this animal, by making it pafs through the mercury, and left the interior air to become of the temperature of the atmofphere, it was reduced to 240.25 inches. Having afterwards abforbed the fixed air by cauftic alkali, there remained 200.56 inches of air. In this experiment, therefore, there were 46.62 inches of pure air changed, and 37.96 inches of fixed air produced, making an allowance for the fmall quantity of fixed air contained in the pure air of the veffel. Now of the volume of pure air thus changed, 0.814 will be it's volume diminifhed by refpiration; whilft in the combuftion of charcoal the volume of air is diminifhed in the ratio of 1 to 0.74828. This difference may in fome degree arife from the difference of meafure, but perhaps more fo from letting a little of the exterior air penetrate into the veffel on introducing the animal.

The weight of the fixed air produced in the above experiment is 26.572 grains; from which it follows, that in the fpace of ten hours the animal would have produced 212.576 grains of fixed air.

On determining the quantity of fixed air produced by a guinea-pig in common atmofpherical air, it was found to amount to 236.667 grains in ten hours; which differs about one ninth from the preceding experiment, arifing probably from the difference of fize in the two animals.

A third experiment, made upon a guinea-pig in dephlogifticated air, afforded 226 grains of fixed air in ten hours.

On taking the medium of thefe experiments, and fome

others made by thefe chemifts, both in dephlogifticated
and atmofpherical airs, it appears that the quantity of
fixed air generated by the refpiration of the guinea-pig in
ten hours amounts to 224 grains. Since thefe experi-
ments were made at a temperature of 14 or 15 degrees,
thefe chemifts think it poffible that the quantity of fixed
air may be fomewhat lefs than at a temperature of zero,
which was that of the interior part of the veffels : hence,
to be more exact, the products of fixed air ought to be
determined at this laft temperature. Having proved, by
experiment, that in the combuftion of charcoal the for-
mation of one ounce of fixed air is able to melt 26.692
ounces of ice, it follows that the formation of 224 grains
of fixed air ought to melt 10.38 ounces. Confequently
this quantity of melted ice reprefents the heat produced
by the refpiration of a guinea-pig during ten hours.

In the experiment on the animal heat of a guinea-pig,
it was taken from under the glafs veffel nearly of the fame
heat with which it was introduced ; for it is well known
that the interior heat of animals is always nearly the
fame, but, without a continual renewal of this heat, what
it poffeffed at firft would be entirely diffipated, like that of
n inanimate body : this heat therefore which it commu-
nicates to the furrounding fubftances, and which in this
experiment was communicated to fome ice placed under
the veffel, of which it melted in ten hours thirteen
ounces, is renewed by it's vital functions. This quantity of
melted ice reprefents, therefore, nearly the heat renewed
in that fpace of time by refpiration. Perhaps it may be
neceffary to fubtract a couple of ounces or more, fince
the extremities of the body of the animal became cooled
in the veffel, although the interior of the body preferved
nearly the fame temperature : befides, the humours eva-
porated by it's internal heat melted, on cooling, a fmall

quantity of ice, and united with the water which ran from the veffel.

On deducting, therefore, about two ounces and a half from this quantity of ice, the remainder will be the quantity melted by the refpiration of the animal; and if the errours which are inevitable in fuch experiments be confidered, perhaps a more perfect coincidence between thefe refults cannot be expected.

Hence, according to thefe chemifts, the heat difengaged during the converfion of pure into fixed air by refpiration may be confidered as the principal caufe of the prefervation of animal heat; and if other caufes concur in it's fupport, their effect is inconfiderable.

From thefe experiments thefe chemifts conclude that refpiration is a combuftion, which, although very flow, Refpiration is perfectly fimilar to that of charcoal; that it takes place is a perfect combuftion. in the interior part of the lungs without difengaging any fenfible light, becaufe the matter of fire, become free, is immediately abforbed by the humidity of thefe organs; that the heat thus extricated in this combuftion is communicated to the blood which traverfes the lungs, and is from thence diftributed all over the fyftem. Hence the air we breathe ferves two purpofes equally neceffary to our prefervation—it takes from the blood the bafis of the fixed air, the fuperabundance of which would be hurtful; and the heat depofited in the lungs by this combination repairs the continual lofs of heat brought about by the atmofphere and furrounding bodies.

Animal heat is nearly the fame in all parts of the body; which effect appears to depend on the three following caufes: Caufes of the equality of animal heat.

1ft. The rapidity of the circulation of the blood, which tranfmits immediately, even to the extremities of the body, the heat it receives in the lungs.

2d. The evaporation produced by the heat in thefe organs, and which diminifhes the degree of their temperature.

3d. The augmentation obferved in the fpecific heat of the blood, when it is deprived of the bafis of fixed air it contains by the contact of the pure air: hence, a part of the fpecific heat developed in the formation of the fixed air is abforbed by the blood, it's temperature remaining always the fame; but when in the circulation the blood comes to receive again this bafis of fixed air, it's fpecific heat diminifhes, and fome heat is extricated; and as this combination is made in all parts of the body, the heat it produces contributes to fupport the temperature of the parts diftant from the lungs nearly at the fame degree as that of thefe organs. From this way of reafoning the chemifts eftablifh the following propofitions:

When an animal is in a permanent and tranquil ftate, when it is able to live a confiderable time without fuffering in the medium that furrounds it: in general, when the circumftances in which it is do not fenfibly change it's blood and humours, fo that the animal fyftem after feveral hours undergoes no fenfible variation, the prefervation of the animal heat is owing, at leaft in great part, to the heat produced by the combination of the pure air refpired by animals with the bafis of the fixed air furnifhed by the blood.

Hence, on comparing the heat difengaged by the combuftion of charcoal with the quantity of fixed air formed during this combuftion, the heat developed in the formation of a given quantity of fixed air is obtained: if, then, the quantity of fixed air produced by an animal in a given time be determined, the refult will be the heat arifing from the action of it's refpiration on the air; and it only remains to compare this heat with that which fupports it's animal heat, and to meafure the quantity of ice it

melts in the interior of the veſſel : and if, as has been
found by the preceding experiments, theſe two quantities
of heat are nearly the ſame, it may be concluded that it
is to the change of pure into fixed air by reſpiration that
the preſervation of animal heat is owing, at leaſt for the
moſt part.

In reſpiration, as in combuſtion, it is the air of the at-
moſphere that furniſhes the oxygen and the caloric ; but
as in reſpiration it is the ſubſtance even of the animal,
the blood, which furniſhes the combuſtible part, if ani-
mals did not habitually repair by nouriſhment what they
loſe by reſpiration, the oil would ſoon be wanting to the
lamp, and the animal would periſh like an extinguiſhed
candle. There are even inſtances cited by authors of this
combuſtion being ſo rapid as to conſume the greater part
of the body. Thus a female deſcribed by Wilmer, or the
inflammable woman of Coventry ; the counteſs Cornelia
Bandi, near Ceſena, in Romagna ; another woman at
Chriſt-church, in Hampſhire ; and Grace Pots, at Ipſ-
wich ; were conſumed by an internal fire, ſo eager were
the principles of which they were compoſed to combine,
as Dr. Beddoes ſays, with oxygen. Theſe remarkable
inſtances, however, of quick combuſtion carried on in
the body are very rare.

Extraordinary caſes of rapid animal combuſtion.

The proofs therefore of this identity of effects between
reſpiration and combuſtion are taken immediately from
experience. Indeed, the air that has been reſpired no
longer contains, at it's departure from the lungs, the ſame
quantity of oxygen ; it contains not only carbonic acid
gas, but likewiſe much more water than it did before in-
ſpiration. Now, ſince vital air cannot be converted into
carbonic acid gas without the addition of carbon, or into
water without hydrogen ; and ſince this double combina-
tion cannot take place without the vital air loſing a part
of it's ſpecific heat, the conſequence is, that the effect of

refpiration is to extract a portion of hydrogen and carbon from the blood, and to depofit in their place a portion of it's fpecific caloric, which during circulation is diftributed with the blood into all parts of the animal œconomy, and fuftains that temperature obferved in all refpiring animals, and which, if nothing extraordinary happen, is nearly conftant. It may therefore be faid with the ancient poets, that the torch of life is lighted the moment the infant breathes; a gentle combuftion, productive of the vital flame, which is only extinguifhed by death. Since, during refpiration, a great quantity of carbon and hydrogen from the blood is converted by uniting with the oxygen of the air into carbonic acid gas and water, and confequently a great deal of caloric let loofe; Lavoifier and Seguin have made fome experiments to endeavour to find the quantity of carbonic acid gas and water which is formed; and as there is an aqueous emanation not only from the lungs, but alfo from the furface of the body, which is called *perfpiration*, they were likewife defirous of knowing the quantity extricated from fo large a furface, and of comparing, as near as circumftances would permit, the connexion arifing between refpiration, perfpiration, and digeftion. The invifible vapour or emanation that takes place from the furface of the body they have called *cutaneous perfpiration*; and that which is extricated from the lungs at each expiration, *pulmonary perfpiration*.

Experiments of Seguin and Lavoifier to determine the quantity of carbonic acid gas and water formed during refpiration, &c.

Sanctorius was the firft who undertook to make experiments on the cutaneous perfpiration : for this purpofe he placed himfelf in a chair adapted to a pair of fcales, and he determined the quantity of perfpiration by the lofs of weight he experienced.

Before his time, nothing but conjecture determined the effects of this cutaneous function; and although this philofopher was the firft experimental inquirer on the fubject, many things were wanting to make him fuccefsful.

3

The phenomena of refpiration, and the formation of water and carbonic acid which accompanies it—the two fpecies of evaporation, one of which is effected by folution in the air, and the other by the fimple combination of caloric with the evaporated liquor, were unknown. It was not even fufpected that the principal caufes which influence refpiration are the greater or lefs denfity of the air, it's temperature, and it's degree of drynefs or humidity. Sanctorius, deprived of thefe preliminary facts, confounded all the effects which arofe from his experiments.

In order to feparate the cutaneous perfpiration, thefe two chemifts made ufe of a garment of filk, coated with elaftic gum, fo as to prevent the air and humidity from penetrating. When this was put on, it was tied at the top of the head by a ftrong ligature, whilft a tube was adapted to the mouth, fo as not to let any air efcape, to breathe through: hence, whatever was refpired paffed externally, and whatever perfpired, internally.

By being weighed on entering this apparatus, and after having departed from it, the difference gave the lofs of weight owing to the united effects of refpiration and perfpiration; and by being weighed a few inftants after having entered and before departing from it, the lofs of weight owing only to the effects of refpiration was obtained.

The greateft difficulty which the chemift had to contend with was the feparation of the products of refpiration, of pulmonary and of cutaneous perfpiration; for it is neceffary to know, that there continually oozes into the lungs an humour feparated from the blood, which filters through the membranes of the lungs, and which is compofed principally of hydrogen and of carbon.

It is this humour which, being greatly divided at the moment it comes from the fmall extremities of the exhaling veffels of the lungs, is in part confumed by decompofing

the vital air with which it was in contact, and forms
during this combustion water and carbonic acid gas. It
is not aftonishing that this combustion should exift in the
lungs, when it is feen that dung, the nature of which ap-
proaches much to that of blood, burns at the ordinary
temperature of the atmofphere, *i. e.* at 8° or 10°.

The carbonic acid gas therefore, formed during refpira-
tion, being in a fluid ftate, it is eafily conceived how it is
evacuated by the action of the lungs at the moment of
expiration; but the cafe is not fo with the water formed
at the fame time. It would foon accumulate in the
bronchia, if nature had not the means of evacuating it,
one of which is this. The air enters cool into the lungs;
it departs from it with a heat nearly equal to that of the
blood: now the hot air diffolves more water than cold
air, and it is from this increafe of caloric that it carries
away with it the water exifting in the lungs.

This water is of two forts; 1. that which oozes with
the carbonated hydrogen, or the water of pulmonary per-
fpiration, properly called. 2. That which is formed by
the combination of the oxygen of the air with the hydro-
gen of the blood, or the water of refpiration.

Thefe chemifts were able to obtain the refpective quan-
tities of thefe two portions of water.

The apparatus they made ufe of was fo difpofed as to
be able to meafure, with great exactitude, the quantity of
water and of carbonic acid exhaled, as well as the quan-
tity of air before and after the experiment; for it is eafily
conceived, that being acquainted on the one fide with the
total fum of the water come from the lungs, and on the
other, the quantity of carbonic acid gas formed, it would
be eafy to determine, by a very fimple calculation, the
quantity of water formed, and the quantity of water
owing to the pulmonary perfpiration. But in the folu-

tion of this problem, it is taken for granted, that all the
carbonic acid gas difengaged at each expiration is formed
in the lungs, and during circulation.

If the carbonic acid gas difengaged during expiration
was in part the product of digeftion, the confumption of
vital air in the act of refpiration muft be attributed to
another caufe. The fuppofition muft be, that more
water is formed, either in the lungs or during circulation;
and then the pulmonary perfpiration would be found to be
diminifhed by all the quantity of water which muft be
attributed to this formation; or it muft be granted, that a
part of the vital air, being abforbed in the lungs, unites
during circulation with fome part of our fyftem.

The increafe of menftrual power, which the air ac-
quires by being heated in the lungs, is in general fufficient
to evacuate, by way of folution, the two portions of
water juft mentioned; viz. that arifing from the pulmo-
nary perfpiration, and that formed by the combination of
oxygen and hydrogen. In this refpect, nature appears to
make ufe of fome very curious means of compenfation.
If the quantity of water which oozes through the bron-
chial membranes be too abundant; if the air of refpira-
tion, already loaded with water that is formed, is not in
a ftate to diffolve it in fpite of the efforts of a more ac-
celerated refpiration, and in fpite of the increafe of caloric
proceeding from it, which increafes the menftrual power
of the air; the excefs is carried back again into the cir-
culation by the abforbent veffels of the lungs, or expec-
torated under another form.

It is eafy to conceive how all thefe caufes muft in-
fluence the phenomena of perfpiration; that it is accele-
rated or retarded according to the neceffity of the ma-
chine—that it ought fometimes to form more water,
fometimes more carbonic acid gas—that, in fhort, the
pulmonary perfpiration can be augmented or diminifhed
by an infinity of circumftances.

Thefe chemifts found, that the lofs of weight of a perfon in an ordinary ftate varies from 11 grs. a minute to 32; *i. e.* in 24 hours from 1 lb. 11 oz. 4 drs. to 5lbs. comprehending the effects of cutaneous and pulmonary perfpiration, and of refpiration. Taking the medium, the lofs of weight is 18 grs. per minute; and fuppofing it to continue uniformly, it will be 1 oz. 7 drs. an hour, and 2 lbs. 13 oz. in 24 hours.

	lb.	oz.	drs.
Of thefe 2 lbs. 13 oz. there belong to cutaneous perfpiration - - - -	1	14	0
And to the effects of refpiration - -	0	15	0
Total - -	2	13	0

On decompofing the effects of refpiration, it will be found, on a medium,

1. That an individual confumes 38413 cubic inches of vital air in 24 hours, *i. e.* a little more than 22 cubic feet, or 33 oz. 1 dr. 10 grs.

2. That of this quantity there is employed to form water a little more than — 13 cubic feet,

And to form carbonic acid a little lefs than — 9

— 22

3. That the volume of carbonic acid gas, difengaged from the lungs in 24 hours, is 14930 cubic inches, *i. e.* about 9 feet 6 cubic inches, which are compofed of carbon -

	lb.	oz.	drs.	grs.
carbon	0	5	7	0
oxygen -	0	12	0	4
Total - -	1	1	7	4

4. That the weight of the water, formed in the lungs in 24 hours, amounts to 1 lb. 7 oz. 5 drs. 20 grs., which are compofed of

	lb.	oz.	drs.	grs.
Hydrogen	0	3	3	10
Oxygen	1	4	2	10
Total	1	7	5	20

5. That the quantity of water difengaged ready formed by pulmonary perfpiration, is 5 oz. 5 drs. 62 grs. in 24 hours.

	lb.	oz.	drs.	grs.
Laftly, That uniting together the water difengaged in 24 hours, by cutaneous perfpiration, which amounts to	1	14	0	0
That difengaged by pulmonary perfpiration	0	5	5	62
The quantity of carbon confumed in the fame time	0	5	7	0
And the quantity of hydrogen	0	3	3	10
The total lofs of weight of a perfon in 24 hours is	2	13	0	0

Thefe refults are only to be eftimated as probable. Seguin and Lavoifier have likewife obferved, that without being very particular in taking daily the fame quantity of nourifhment; without reftraining themfelves to live by rule, provided excefs and irregular hours of repaft are avoided ; the fame individual, after having been increafed in weight by all the aliments, returns every day, after the revolution of about 24 hours, to the fame weight he had the evening before. If this effect does not take place, it is the confequence of difeafe.

It is by experience only that man can become ac-

quainted with nature; and the more he interrogates her, the more will he be delighted with her wifdom. " Our " admiration," fays the chemift, " cannot be fatigued " with viewing the fyftem of general liberty which na- " ture appears to have been defirous to eftablifh in every " thing relative to the animal machine. In giving it life " and fpontaneous motion, an active energy, neceffities " and paffions, fhe has not interdicted the ufe of them. " She was even defirous that he fhould be free in their " abufe, but prudent and wife; fhe has every where fur- " rounded him with regulators; and fhe has added fa- " tiety to the fuperabundance of enjoyment."

Animal machine governed by three principal regulators.

The animal machine is therefore governed by three principal regulators: *refpiration,* which by operating in the lungs, and perhaps likewife in other parts of the fyftem, a flow combuftion of the hydrogen and carbon contained in the blood, produces a difengagement of caloric abfolutely neceffary to the fupport and exiftence of animal heat: *perfpiration,* which, by occafioning a lofs of the perfpirable humour, facilitates the difengagement of a certain quantity of caloric neceffary to the folution of this humour in the furrounding air; and confequently prevents, by the continual coldnefs this difengagement produces, the individual from receiving a degree of heat or temperature fuperior to what is fixed by nature: and *digeftion,* which, furnifhing the blood with water, hydrogen, and carbon, reftores habitually to the animal machine what it lofes by perfpiration and refpiration, and afterwards rejects externally fubftances that are hurtful or fuperfluous to it.

If the caufes which affect man are various, his refources are equally multiplied: his temperament is either adapted for motion or repofe, for abftinence or excefs of nourifhment. Similar circumftances permit him to pafs from an active to a tranquil life, according to his necef-

fities or his will. If he be in a ſtate of inaction and re-
poſe, the circulation is flow as well as the reſpiration, he
conſumes leſs air, exhales leſs carbon and hydrogen from
the lungs, and conſequently has leſs need of nouriſhment.
If he be obliged to work hard, the reſpiration is accele-
rated; he conſumes more air, loſes more hydrogen and
carbon, and conſequently has need of oftener repairing
what is loſt, by a greater quantity of nutrition. In run-
ning, dancing, and in all violent exerciſes, whatever ac-
celeration the reſpiration and circulation undergo, or
whatever increaſe there is in the conſumption of air, of
hydrogen and carbon, the equilibrium of the animal
œconomy is not diſturbed, whilſt the aliments more or
leſs digeſted, always more or leſs in reſerve in the in-
teſtinal canal, ſupply their loſs; but if the expenſe made
by the lungs be greater than the receipt made by nutri-
tion, the blood is deprived by degrees of it's hydrogen
and carbon, and diſeaſe ſucceeds. In this caſe the ani-
mal is adviſed of the danger by laſſitude, loſs of vigour,
and he finds the neceſſity of reeſtabliſhing the equili-
brium by nouriſhment and repoſe. The contrary takes
place, for want of motion and exerciſe or the uſe of cer-
tain aliments, or any imperfection or vice in the organs
of nutrition or reſpiration. In theſe caſes, the digeſtion
introducing into the blood more matter than the reſpira-
tion can conſume, an exceſs of carbon or of hydrogen
takes place in the maſs of blood, or perhaps both at the
ſame time. Nature then ſtrives againſt this alteration in
the humours; and if ſhe cannot recover the equilibrium
by a more frequent reſpiration, diſeaſe is the conſequence.

" Whilſt," ſay theſe two chemiſts, " we only con-
" ſidered the conſumption of air in reſpiration, the lot
" of the rich and the poor was the ſame, for the air be-
" longs to all, and coſts nothing: the labourer even,
" from his greater energy, enjoys more completely this

" gift of nature: but since experience has proved re-
" spiration to be a real combustion, that consumes at
" each instant a portion of our substance, that this con-
" sumption is the greater in proportion as the circulation
" and respiration are accelerated, that it increases accord-
" ing to the more laborious and active life of the indi-
" vidual—a multitude of moral reflexions arise of them-
" selves from such effects. By what fatality happens it
" that the poor man, who lives by the sweat of his brow,
" and is obliged to expend the force which nature allots
" him, consumes more than his idle neighbour, whilst
" this last has less need of repairing?"—" Why," ex-
claim these humane chemists, " by a shocking con-
" trast, does the rich man enjoy an abundance which is
" not physically necessary for him, and which would
" seem to be destined for the daily labourer? Let us
" not however calumniate Nature, and accuse her of
" faults that undoubtedly belong to human institutions,
" and which are perhaps not to be separated from them.
" Let us be content to bless philosophy and humanity,
" which unite to procure us superior enjoyment and
" happiness, and add to those of the indigent."

This result of forces continually varying and conti-
nually poising each other, which are observed at each
moment in the animal œconomy, is truly to be admired.
Man, in this respect, has been more favoured by nature
than any other animals; he lives equally in all tempera-
tures and in all climates : if he finds himself in a cold cli-
mate, the contact of the air with the lungs, from it's
greater density, becomes more considerable ; more air is
decomposed, more caloric disengaged, which repairs the
loss caused by the external cold ; whilst the perspiration
diminishes, evaporation becomes less, and consequently
the cold.

If he passes into a hot climate, the contrary effect takes

place. The air being lefs denfe, it's contact with the blood is lefs confiderable; lefs air is decompofed, lefs caloric is difengaged, a more abundant perfpiration is eftablifhed, a greater quantity of heat taken away ; and it is in this manner that an almoft uniform degree of heat is obferved in animals that breathe, which is about 32° of Reaumur.

Whilft the variation of the effects does not pafs over the limits affigned by nature, whilft the means of compenfa- tion fhe employs are fufficient, the animal is in a ftate of health. But if the refpiration takes more or lefs hydro- gen and carbon by the lungs, than digeftion can fupply ; if the perfpiration and frigidity it occafions in concert with the exterior air do not take away all the caloric arifing from the decompofition of the vital air in the lungs, or in any other part of the fyftem; if, in fhort, through- out, the receipt is not equal to the expenfe, the animal machine is foon difturbed, and the blood changes it's quality, either from excefs or want of hydrogen and of carbon, or both at the fame time.

Thefe two philofophers therefore, Crawford and La- voifier, agree in looking upon the pure air as the princi- pal fource of the heat extricated in combuftion and re- fpiration : but there appears to be an effential difference in their opinions, which confifts in this, that Lavoifier thinks, that the heat, difengaged during thefe two pro- ceffes, is combined with the pure air ; and that this fluid owes it's aëriform ftate to the expanfive force of this combined heat : inftead of which, according to Craw- ford, the matter of heat is in a free ftate in the pure air ; and it is only difengaged, from the pure air lofing a great part of it's fpecific heat on combination. Crawford fup- ports this affertion by experiments, by which he finds the fpecific heat of pure air to be 67 times greater than that of common water.

I 3

Girtanner differs in opinion from Lavoifier and Craw-
ford : he believes, that during refpiration one part of the
oxygen of the vital air combines with the venous blood,
the deep colour of which it changes to a vermilion ; that
a fecond portion of the oxygen unites to the carbon con-
tained in the carbonated hydrogenous gas, which exhales
from the venous blood, and forms carbonic acid gas ;
that a third portion of the oxygen unites to the carbon of
the mucus which the lungs contain in large quantity,
and which is continually decompofing. This part like-
wife forms carbonic acid gas. A fourth part of the oxy-
gen combines with the hydrogen gas of the blood to form
water, which exhales during refpiration. The caloric
which the decompofed vital air contained *remains in part
united* to the oxygen and to the blood : hence the quan-
tity of fpecific heat of the arterial blood, which is greater
than that of the venous ; another part of the caloric en-
ters into the combination of the carbonic acid gas ; and,
laftly, a third part produces the neceffary temperature
for the formation of water, by the combination of hydro-
gen and oxygen gafes : confequently the *effects* of refpi-
ration fhould be,—

1. The venous blood lofes the carbonated hydrogenous
gas it contains, and abforbs oxygen gas, which gives it
a vermilion colour, fuch as it gives to metallic oxyds, to
the nitrous acid, and to feveral other fubftances with
which it is combined.

2. The capacity of the blood is augmented, becaufe
oxygen increafes the capacity of all fubftances with which
it unites.

3. The oxygen gas of the atmofphere is in part ab-
forbed by the venous blood, partly changed into carbonic
acid gas, by the carbon of the blood and that of the
mucus of the lungs, and partly into water by the hydro-
gen gas of the blood, and the great quantity of caloric
become free.

The *products* of refpiration fhould be,

1. A fluid animal oxyd; 2. carbonic acid gas; 3 wa-ter; 4. a fmall quantity of caloric become free.

Hence it follows, that refpiration is a procefs exactly analogous to combuftion and the oxydation of metals; during circulation the blood lofes it's oxygen, and be-comes loaded with carbonated hydrogenous gas, by means of a double affinity; during the diftribution of oxygen through the fyftem, the caloric united to this oxygen becomes free, and produces animal heat; and the greater capacity of arterial blood for caloric is only owing to the oxygen to which it is united in the lungs.

Another opinion refpecting the procefs of refpiration De la is that of de la Grange. Confidering that, if all the Grange. heat diftributed through the animal fyftem arofe in the lungs, their temperature would be fo very great as to caufe fear left it fhould conftantly deftroy them; and that, if the temperature of the lungs is fo extraordinarily different from that of the other parts, it muft have been long ago obferved; he thinks he can conclude with great proba-bility, that all the heat of the animal œconomy is fepa-rated not only in the lungs, but in all parts wherever the blood circulates. For this purpofe, he therefore fup-pofes, that the blood on paffing through the lungs dif-folves the oxygen of the infpired air; that this diffolved oxygen is conveyed by the blood into the arteries, and thence into the veins; and that during circulation the oxgen quits by degrees it's ftate of folution to com-bine partially with the carbon and hydrogen of the blood, and form the water and carbonic acid which is extricated from it as foon as the venous blood goes from the heart in order to enter the lungs; and from this man-ner of explanation this chemift thinks that the fmall difference may be eafily accounted for which is found between the temperature of the lungs and that of the other

internal animal parts, and how the caloric may arrive at
the extreme parts the moſt diſtant from the lungs.

Haſſenfratz.   The opinion of Haſſenfratz reſembles the laſt: he
thinks that caloric is not only diſengaged in the lungs,
but during the circulation by the union of the hydrogen
and carbon of the blood with the oxygen which is inter-
mixed with it; and as caloric is extricated during this
union, and this caloric ſupports the animal heat; and as
this union takes place for the moſt part during the cir-
culation of the blood as it paſſes from the lungs into
the arteries, and thence by the veins into the lungs, it
follows, that the greateſt part of the caloric is ſeparated
during this circuit.   This chemiſt explains the experi-
ment of Dr. Crawford, or gives the cauſe why the ar-
terial blood acquires a greater ſpecific heat than the ve-
nous; and this he ſays may be done two ways:—1. As
all oxydated ſubſtances have a greater proportionable heat
than ſimple ſubſtances, and as the arterial blood with re-
ſpect to the venous may be looked upon as oxydated, the
firſt muſt have a proportionably greater heat than the laſt.
2. As the oxygen in the arterial blood ſtill contains al-
moſt all it's caloric, and this is afterwards extricated in
circulation by the union of the oxygen with the hydro-
gen and carbon of the blood—the venous, in which this
combination is made, contains no more caloric, it having
been diſengaged and diſperſed to warm all the parts through
which the blood has paſſed: hence the venous blood
ought to have comparatively leſs heat than the arterial.
Hence the lungs are not the ſtove of animal heat, but the
caloric in order to ſupport it is extricated during circula-
tion.

Gren.   According to Gren, the oxygen gas does not give up
it's baſis to the arterial blood: he aſſerts, that all the
water we expire is of new formation, and not ſeparated
from the blood; that conſequently oxygen is only ab-

forbed for the formation of water and of carbonic acid, and that there remains none of it to combine with the blood: further, that the change of the venous into the arterial blood in the lungs does not depend upon the abforption of oxygen, but on the feparation of the carbon and hydrogen; and that the arterial and not the venous blood is a ftimulus to the heart.

Another theory on this fubject is given by de la Me-therie. This chemift does not believe the conclufions drawn by Lavoifier and Seguin, having found that,

1. In an ordinary infpiration, no more than from four to fix inches of air enter the lungs.

2. He admits three caufes of animal heat.

a. Caloric, which is difengaged from the pure air that undergoes a combination in the lungs.

b. Mufcular motion; for in fleep the animal heat is lefs than when awake; and in local inflammation, the heat of the part is confiderably raifed.

c. Finally, the fermentation of animal fubftances in the ftomach and inteftines, during which fermentation caloric is difengaged; for animal matter during this pro-cefs is known to be heated even to the point of inflam-mation.

3. Refpiration likewife ferves as a conductor of the electric fluid; for, from the experiments of Read, the air of an apartment in which a perfon has breathed for a few hours is always electrified negatively, whilft before it was in a pofitive ftate of electricity.

The laft theory on refpiration is that of Davy. This ingenious philofopher having from experiment laid it down as a fact that the caloric of the fyftem of Lavoifier is not the matter of heat, or an imaginary fluid, as has been fuppofed; but that it may be defined a peculiar motion, or probably a vibration of the corpufcles of bodies tending to feparate them; and hence may with

propriety be called *repulsive motion*; and having substi-
tuted for oxygen gas the term phos-oxygen (from φως light,
οξυς acid, and γεννπτωρ generator), to express a chemical
combination of the simple substance light with the sim-
ple substance oxygen; having proved that the oxygen gas
of the French nomenclators, which they have supposed
to be oxygen combined with caloric, is a substance com-
pounded of light and oxygen; and having explained the
theory of combustion; he first offers some objections
against the theory of respiration of the calorists.

1st. Against it's being supposed that one portion of the
oxygen combines with the iron in the blood, giving the
vermilion colour to the arterial blood, he asserts that iron
never decomposes phos-oxygen at so low a temperature as
98°, the greatest heat of the lungs; and phos-oxygen is
never decomposed by iron, without rapid combustion,
flame, and great heat.

2d. Oxygen gas is never decomposed by carbon at so
low a temperature as 98°, and is never decomposed with-
out combustion, &c.

3d. There is never a decomposition of phos-oxygen
by hydrogen at so low a temperature; and it is well
known that this process does not take place without flame:
hence the theory is false. On the contrary, Davy under-
takes to prove from experiments,

1st. That phos-oxygen (light and oxygen) is not de-
composed in the lungs;

2d. That phos-oxygen combines with the venous blood
in the lungs;

3d. That carbonic acid and water are both liberated
from the lungs during this process, either by the increase
of temperature, or from the superior affinity of phos-
oxygen for the venous blood.

First experiment.
A phial containing twelve cubic inches and a half was
filled with very pure phos-oxygen. The medial vein of a

healthy man was opened, and the ftream of blood di-
rected into the phial. The mouth of the phial was im-
mediately brought into contact with the arm, fo as en-
tirely to exclude all external air. The room was then
darkened.   As the blood flowed into it, it changed from
a dark red to a bright vermilion colour.   When the phial
was half full, it was clofed, and plunged in mercury heated
to 90°. Having remained half an hour, the blood was
found coagulated, and a bright vermilion colour : fome
drops of water were formed on the fides of the phial.
When the cork was drawn, about two cubic inches of
mercury rufhed into the phial; from which he concluded
an abforption of gas had taken place. The remaining gas
was three cubic inches and one tenth of phos-oxygen,
with nine tenths of a cubic inch of carbonic acid.

During the experiment no light was liberated : hence
Davy fuppofes there was no decompofition of phos-oxy-
gen.   And as a confiderable diminution of phos-oxygen
took place, and the blood acquired new properties, he
concludes that phos-oxygen is capable of combination
with the venous blood.   To prove this by analyfis as well
as fynthefis, he made the following experiment :

A twelve-cubic-inch phial, with a pneumatic apparatus Second ex-
affixed to it, was filled with arterial blood from the caro- periment.
tid artery of a calf. The phial was placed in a fand bath
of the temperature of 96°, and the heat gradually and
flowly raifed. In about ten minutes the temperature of
the bath was 108°, and the blood began to coagulate. At
this moment fome globules of gas were perceived paffing
through the tube. Gas continued to pafs, in very fmall
quantities, for about half an hour ; when the temperature
of the fand was about 200°. The blood was coagulated,
and almoft black. About one cubic inch and eight tenths
of gas were collected in the mercurial apparatus : of this
one cubic inch and one tenth were carbonic acid, and the

remaining feven tenths phos-oxygen. Great caution is
neceffary in this experiment; for, if the temperature is
not gradually and flowly increafed, the liberated gafes are
carbonic acid and hydrogen.

From the above experiment it is evident that the arte-
rial blood contains phos-oxygen; and it was before proved
by fynthefis that it is capable of combining with it di-
rectly : hence he concludes that phos-oxygen combines
with the venous blood of the fyftem in the pulmonary
veffels.

As no light was liberated in the firft experiment, it is
evident there cannot be even a partial decompofition of
phos-oxygen in refpiration ; and confequently, the car-
bonic acid and aqueous gas liberated cannot arife from the
decompofition of phos-oxygen by the carbon and hydro-
gen of the venous blood—they muft therefore be libe-
rated from the venous blood. To prove this more clearly,
the following experiment was made :

Third expe-
riment.
A fmall fheep's bladder was filled with blood from the
medial vein of a healthy woman. This blood never came
into contact with any air during the experiment. The
bladder was inferted in a veffel of water heated to 112°,
and the gafeous products received by a pneumatic appa-
ratus. They were carbonic acid and aqueous gas.

Refpiration is therefore, according to the theory of
Davy, a chemical procefs—the combination of phos-
oxygen with the venous blood in the lungs, and the libe-
ration of carbonic acid and aqueous gas from it. From
the combination and decompofition arifes an increafe of
repulfive motion, which, combined with that produced
by the other chemical proceffes taking place in the fyf-
tem, and that generated by the reciprocal action of the
folids and fluids, is the caufe of animal heat.

Dr. Men-
zier's at-
tempt to
An attempt has been made by Dr. Menzies, or rather
he informs us he has ventured to examine, how the

afcertainment of the quantity of air ufually refpired may throw light on the generation of animal heat, and on the quantity of heat generated in a given time ; and he is of opinion, that this can be eftimated independently of any theory on the nature of heat itfelf.

The experiments of Crawford, Lavoifier, and de la Place, prove, when equal quantities of air are vitiated by refpiration and combuftion, that equal degrees of heat are evolved. Crawford found, that if an animal be fhut up in a veffel furrounded with water and protected from the accefs of air by very foft wool, one hundred meafures of air, each containing an ounce, vitiated either by this animal's refpiration or by the combuftion of wax or coal, communicated the following quantities of heat to 31 lbs. 7 oz. of water.

Degrees.

100 meafures of air vitiated by { The combuftion of coal, gave 19.3 ——————— wax, ... 21.0 The refpiration of a guinea pig, ... 17.3

But as each degree of Crawford's thermometer makes only one tenth of a degree of Fahrenheit's, it is evident, that, if a thoufand fuch meafures were vitiated by the combuftion of wax and the refpiration of a guinea-pig, the difference between the quantities of heat given out to 31 lbs. 7oz. of water will make 3.7 degrees of Fahrenheit's ; the difference between the quantities given out by the combuftion of coal and the refpiration of a guinea-pig will be equal to 2 degrees of Fahrenheit's thermometer : i. e. the heat communicated to the water by the guinea-pig will be two degrees lefs than that communicated by the combuftion of coal.

But from the feries of experiments of Lavoifier and de la Place (Mémoire fur la Chaleur, 1783) it appears, that the heat communicated by the refpiration of a guinea-pig,

when equal quantities of air were vitiated, was greater
than that generated by the combuſtion of coal in the pro-
portion of 13 to 10.3. But as contemporary authors
have ſuppoſed the degree of heat ſaid to be communicated
by the guinea-pig to be ſomewhat exaggerated, and as the
reſult of their experiments was almoſt the ſame, Dr.
Menzies thinks the average number may be taken as a
rule—the difference probably proceeding from the diffe-
rent conſtruction of the inſtruments employed : hence it
is conceived, that when equal quantities of air are viti-
ated, whether by reſpiration or the combuſtion of coal,
nearly equal quantities of heat are generated.

As the quantity of heat generated when a given quan-
tity of fixed air is produced by the combuſtion of coal
has been lately demonſtrated by Lavoiſier (Elements of
Chemiſtry, p. 101), and as the quantity of air uſually re-
ſpired has been aſcertained : it is evident that the quan-
tity of heat generated in the lungs, in any given time,
could be alſo found out, if the quantity of fixed air was
eſtimated in the air that has been once breathed.

*by eſtimat-
ing the
quantity of
fixed air in
reſpired air.
Firſt expe-
riment.*

The following experiments were made with this view :
A quantity of air once reſpired was preſſed out of an
allantoid into a glaſs bottle inverted in water ; and, left
any part of the fixed air ſhould have been abſorbed by the
water, ſome oil was previouſly poured into the bottle.
The bottle was then inverted into another veſſel filled
with cauſtic alkali. The barometer was in the mean time
attended to, and the degree of heat marked by a thermo-
meter. The air in the bottle was then ſhaken, and left
in contact with the cauſtic alkali till all the fixed air was
abſorbed. Then the bottle was again plunged into the
water, till the cauſtic alkali in the bottle and the water in
the veſſel were at the ſame height. The bottle being then
ſtopped with a cork, and placed on it's bottom, it con-
tained a quantity of cauſtic alkali, which, accurately

'weighed, gave the quantity of fixed air abforbed, after fome corrections being made on account of the afcent and defcent of the mercury in the barometer, and the difference of temperature in the bottle.

Thus the bottle contained 2038.5 cubic inches; the temperature of the air of the bottle was 59° of Fahrenheit; the altitude of the mercury in the barometer was 29.07 inches. The temperature of the air, after two days, was 57.5°; the altitude of the mercury in the barometer was 29.37 inches; the cauftic alkali of the bottle weighed 5 lbs. $9\frac{1}{2}$ oz., equal to 131.2713 cubic inches. But, on account of the afcent of the barometer, it is neceffary to fubtract 2.09 cubic inches, and 6.471 cubic inches, be-caufe the air in the bottle was rendered 1.5° (of Fahrenheit) colder: for as the volume of elaftic fluids is in the inverfe proportion of the weight preffing on them, 29.37 : 29.07 : : 2038.5 : $x = 2017.6$: and 2038.5 — 2017.6 = 20.9.

And as atmofpheric air is expanded $\frac{1}{472.5}$ of it's vo-lume for every degree of Fahrenheit's thermometer $\frac{2038.5}{472.5}$ × 1.5° = 6.471. So 131.2713 — 20.9 — 6.471 = 103.9, the number of cubic inches of fixed air in 2038.5 inches of air once refpired; a quantity lefs than one nineteenth of the whole; for $\frac{2038.5}{103.9} = 19.6$. But, left any part of the fixed air fhould be abforbed, oil was ufed inftead of water.

The bottle was filled with air once refpired and paffed Second ex- through oil: this bottle contained 179.812 cubic inches. periment.

The thermometer and barometer were as in the laft ex-periment. The cauftic alkali, after two days, weighed $6\frac{1}{20}$ oz. and meafured 11.451 cubic inches. But 29.37 : 29.07 : : 179.812 : $x = 177.973$; and 179.812 — 177.973 = 1.839; and $\frac{179.812}{472.5} \times 1.5° = 0.5707$.

Thus 11.451 — 1.839 — 0.5707 = 9.042, the quantity of

fixed air in 179.8 cubic inches of air once refpired; for $\frac{179.812}{9.042} = 19.8.$

The fame experiment being repeated with the fame bottle, 3 oz. 1 dr. only of cauftic alkali, meafuring 5.9148 cubic inches, were found in the bottle. But as during this time the mercury in the bottle had fallen fix tenths of an inch, 3.817 cubic inches muft be added to that quantity. And as the air in the bottle was found eight tenths of a degree colder towards the end than at the beginning of the experiment, 0.3044 parts of an inch are to be fubtracted from it.

For $29.2 : 29.82 :: 179.812 : x = 183.629$; and 133.629 $-179.812 = 3.817$; and $\frac{179.8}{172.5} \times 0.8 = 0.3044.$

So that $5.9148 + 3.817 - 0.3044 = 9.427.$ And $\frac{179.812}{9.427}$ $= 19.07.$

In frequently repeating thefe experiments with the large and fmall bottles, whilft the ftate of the thermometer and barometer was carefully attended to, the greateft variation was 20.1 : fo that the average number will be 19.6.

Dr. Menzies likewife made fome experiments to difcover the quantity of fixed air in the room where thefe were made; but the quantity in 2038.5 cubic inches of air refpired was found to be fo fmall as to fcarcely perceptible. If any calculation be attempted, the quantity of fixed air may be eftimated at $\frac{1}{2}$th or $\frac{5}{100}$dths of air once refpired.

Thus, if the quantity of air commonly infpired be eftimated at 40 cubic inches, and the number of refpirations at 18 in a minute, 720 cubic inches will be infpired in the fpace of a minute; of which quantity only $\frac{27}{100}$dths, or 194.4 cubic inches confift of vital air, the only conftituent of atmofpheric air changed by refpiration.

But $\frac{5}{100}$ parts only of atmofpheric air are changed in each refpiration: hence 36 cubic inches of fixed air are generated in the fpace of a minute in the lungs of a middle-fized man, or 51840 cubic inches in the fpace of a day—a quantity of air weighing 22865.5 grs. or 3.9697 lbs. troy weight. And as Lavoifier has calculated that for every pound of fixed air generated by the combuftion of coal a quantity of heat is evolved which would melt 27.02024 lbs. of ice; and as the fame quantity of heat is generated in air vitiated either by refpiration or by the combuftion of coal; it follows that the quantity of air vitiated daily in the lungs of an ordinary man will give out nearly as much heat as would melt 107.2 lbs. of ice: for $27.02024 \times 3.9697 = 107.2622$. But as a portion of this heat is carried off in the air expired, under the form of fenfible heat; and as a portion is employed in the formation of vapour, or is rendered latent; thefe quantities can be calculated in the following manner :—

As a cubic inch of atmofpheric air weighs 0.32112 parts of a grain, 40 cubic inches will weigh 12.8448 grains. But $\frac{5}{100}$ parts of this quantity being converted into fixed air, if the whole remains free from moifture it will gain 0.19794 : fo that it will weigh 13.04274 grains. Hence the air expired during the fpace of a minute will weigh 234.7693 grains; or that expired during a whole day will weigh 338067.82 grains, or 58.692 pounds. But if air of this kind be fuppofed to have the fame capacity for receiving heat as water, it follows that the fame degree of heat that would raife 58.69 lbs. of water fome degrees, would alfo raife the air to the fame degree. But the quantity of heat requifite to raife 58.69 lbs. of water to the 66th degree of Fahrenheit, is equal to that which would melt 27.6692 lbs. of ice; for fince 140 degrees of heat become latent in the formation of each pound of

water $\frac{58.69 \times 66°}{140} = 27.6692$. Confequently the fame degree of heat will be daily evolved in the lungs under the form of fenfible heat.

The difcovery of latent heat fhows that a great quantity of heat is abforbed during the formation of vapour, without an increafe of temperature ; and, according to the experiments of Watt, the heat thus abforbed, or rendered latent, would raife the temperature of a body of the fame fpecific gravity and capacity for heat as water, although it could not be converted into vapour, 960 degrees more than before.

Dr. Menzies weighed accurately a large allantoid, and then filled it with expired air. When it was quite cooled, and carefully weighed again, it was found to have gained two grains by every refpiration ; which coincides with an experiment made by Hales, who found that fome moiftened diaphragms, through which he had breathed, gained fix grains in three minutes. Thus, if two grains of aqueous vapour be fubtracted every minute, without attending to what may be fubtracted for the difference between the weight of fixed and vital air, 6 oz. or 0.5 of a pound will be fubtracted daily. But if the temperature of a body incapable of being evaporated, of the fame capacity for heat as water, weighing 0.5, be increafed 960 degrees, this heat will diffolve 3.42854 lbs. of ice: for $\frac{960 \times 0.5}{140} = 3.4285$. But as Crawford computes the relative heat of aqueous vapours at 1.55, a quantity of heat will be fubtracted which would diffolve 1 lb. and 0.8856 hundredth parts of ice more than if it's capacity for heat had been the fame with that of water ; or, in other words, all the heat daily confumed in the lungs, in forming aqueous vapour, would diffolve 5.3141 lbs. of ice. So that all the heat daily evolved in the lungs under the

form of fenfible heat and vapour, would diffolve 32.9833lbs.
of ice. For 27.6692 + 5.3141 = 32.9833.

But as it was before demonftrated, that in one day a
quantity of heat was evolved by the change induced in the
air in the lungs, which would diffolve 107.2622lbs. of ice.
Subtract thence 32.9833
                                 ─────────
There will remain 74.2789
which would be the quantity capable of being diffolved by
the heat daily evolved in the lungs of an ordinary man.
But it is neceffary the blood fhould abforb the heat, be-
caufe it is expofed to it's action in the lungs for the fpace
of fome hundreds of fquare feet, and becaufe this fluid is
admirably calculated to diffufe heat through all the body.
The degree to which the blood is heated in it's paffage
through the lungs, may, according to Dr. Menzies, be
eftimated in the following manner :—If the quantity of
blood which paffes through the lungs in the fpace of a
minute may be eftimated at 8 lb. ; if the heart be fuppofed
to propel an ounce and a half in each fyftole; and if the
blood be fuppofed to have an equal capacity for heat with
water ; it is evident that the quantity of heat that would make
8 lbs. of water rife to any given point, would alfo make
8 lbs. of blood rife to the fame point. But as the quantity
of heat abforbed during a day by the blood has been
fhown to be fufficient to diffolve 74.27 lbs. of ice, the
quantity abforbed each minute could only diffolve 0.05158
of a lb. of ice. Befides, fince 140° of heat are requifite
to liquefy 1 lb. of ice, or become latent, $1 : 140 :: 0.05158 : x = 7.22°$, or the quantity of heat requifite for diffolving
0.05158 of a pound of ice would increafe the tempera-
ture of a pound of water by 7.22°, or 8 lbs. by 0.90265 of
a degree of the thermometer of Fahrenheit. Thus the
heat generated each minute in the lungs of an ordinary
man would raife the temperature of the blood paffing

The degree
to which
the blood in
the lungs
is heated
eftimated.

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through them in that space of time, by 0.90265 of a degree, if blood had an equal capacity for heat with water. But as Crawford concludes that the comparative heat of venous blood bears the same proportion to that of water as 0.8928 to 1, it is evident that the same degree of heat which would raise venous blood one degree would raise the same quantity of water only 0.8928 of a degree; or that their temperatures are in the inverse proportion of their capacities for heat.

Thus the quantity of heat would raise the same quantity of venous blood $1.01103°$; for $0.8928 : 1.0000 :: 0.90265 : \frac{0.90265 \times 1}{0.8928} = 1.01103$. And as he found that the capacity of venous blood for heat is increased by it's becoming arterial, in the proportion of 0.8928 to 1.03; if venous blood is raised $1.01103°$ by the heat evolved in the lungs, it follows that arterial blood will be raised only 0.8763; for $1.03 : 0.8928 :: 1.01103 : x = 0.8763$.

Thus 0.13468 parts of a degree of Fahrenheit's thermometer equal the quantity of heat which becomes latent, although the capacity of the blood for heat is increased in the same proportion; for $1.01103 - 0.87635 = 0.13468$.

Therefore the blood in it's passage through the lungs, according to the calculation of Dr. Menzies, gains 1.01103, or more than one degree of Fahrenheit, and it's temperature is increased 0.8763 of a degree. Whence it follows, that the blood in the left side of the heart is warmer than that in the right by eight tenths of a degree. This seems to be confirmed by an experiment of Hunter's on a live dog; for, having introduced the ball of a thermometer two inches within the rectum, the quickfilver rose to 100° and a half exactly. The cheft of the dog was then opened, and a wound made in the left ventricle of the heart; and immediately on the ball being introduced the quickfilver rose to 101° exactly. A wound

was next made fome way into the fubftance of the liver, and the quickfilver rofe to 100° and three quarters. It was next put into the cavity of the ftomach, where it ftood at 101°. All thefe experiments were made in a few minutes.

Hence, according to Dr. Menzies, the quantity of animal heat generated in the lungs may be determined by a method founded on the two following propofitions.

1. That nearly equal quantities of heat are evolved when equal quantities of vital air are vitiated, whether by the combuftion of coal, or by the refpiration of animals.

2. That the quantity of fixed air generated in the lungs in any given time, can be eafily determined by knowing the quantity of fixed air in air once refpired.

This method, therefore, has no connexion with any theory of animal heat, or with the different capacities of fixed and vital air for heat.

Different authors have given the heat of the human body. According to Boerhaave it's natural heat is 92° or at moft 94°; and Pitcairn makes the heat of the fkin to be the fame. It is however evident, that the different parts of the body not only differ from each other, but that they differ from themfelves according to the feafons and other circumftances: hence the difference of the refults amongft phyficians who have attempted to afcertain the animal heat.

Heat of the human body.

Amontons found it to be .... 91, 92, or 93°
Sir Ifaac Newton 95½
Fahrenheit and Mufchenbroek found the blood to be 96
Dr. Martine found the fkin to be .... 97 or 98
——————— ——— the urine 99
Dr. Hales found the fkin 97
——————— the urine 103
John Hunter under his tongue 97
————— in his rectum 98½
————— in his urethra, at one inch 92

K 3

John Hunter in his urethra, at two inches .... 93°
————————————— at four inches 94
———————————— at the bulb of the urethra 97

Such are the phenomena respiration produces in the more perfect animals with warm blood; and such have been the various opinions with respect to the utility of this process, and the part it acts in the animal œconomy. The next part will give an account of the respiration of fishes and insects.

Experi-
ments of
Priestley. *Respiration of Fishes.*—Dr. Priestley having found, according to the phlogistic system, that the principal use of the *lungs* and of the *blood* in man, quadrupeds, and animals with lungs, is to discharge phlogiston from the animal system, in a state proper to diminish respirable air, and to render it unfit for respiration, was desirous of trying whether fishes, which do not breathe like other animals, part with phlogiston to the water in which they live. With this view he put two (a large perch and an eel) into a pail of water; and when they had been in it about twenty-four hours he nearly filled a large phial with the water, and in it he agitated a small quantity of common air between six and seven minutes, and found that it was considerably injured by the operation; for two measures of this and one of nitrous air occupied at first the space of two measures and one sixth, and by standing several days were never less than two measures. But when he agitated an equal quantity of air in the same quantity of the same water in which no fishes had been confined, and for the same space of time, it was not injured in the slightest degree. It is evident, therefore, according to Priestley, that phlogiston is discharged from fishes as well as from other animals; that this phlogiston affects the water, and this water the air that is agitated in it; and in the same manner as the fishes themselves would have affected it, if it had been possible for them to breathe it. Other experiments

confirmed and extended thefe conclufions. Having filled a phial with fome water from the hot well at Briftol, which he found to contain air in a great ftate of purity, he put a few minnows and other fmall fifhes into it, about two inches in length, and confined them without any accefs of common air until they died. He then took equal quantities of the foul and of frefh water, and expelled from both all the air they would yield. That from the water in which no fifhes had been put, or the frefh, exceeded the foul in the proportion of three to two; and by the teft of nitrous air, the former exceeded the latter in a ftill greater proportion. The frefh was about the ftandard of common air, and the foul fomewhat worfe than air in which a candle juft goes out: it might have been worfe, but the water remained in an open veffel all night before the experiment. Hence, air contained in water in an unelaftic ftate is as neceffary to the life of fifhes, as air in an elaftic ftate is to that of land animals.

He then had no doubt but that putting fifhes into water impregnated with air thoroughly phlogifticated would be equally injurious to them, as this air in an elaftic ftate is to land animals; and this was verified. He began with rain water which contained no air, having been recently boiled. He put nine fmall fifhes into a veffel containing about three pints of it, and they lived between three and four hours, no air having been admitted. Two fifhes were put into a pint of it impregnated with phlogifton from air that had been phlogifticated fix months before by means of iron filings and fulphur, and they lived in it nearly an hour. It was very imperfectly impregnated. Inflammable air had a fimilar effect. John Hunter having informed him that fifhes would not live in water impregnated with fixed air, he tried it, and found that fmall fifhes would not live in it more that a few minutes. It is well known that all fpa waters containing fixed air are fatal to fifhes, frogs, and

infects. He found that in water impregnated with nitrous
air they were affected in the same manner, but more vio-
lently ; but as a decompofition of fome fmall part of the
nitrous air might take place before he could poffibly flip
the funnel into the neck of the phial, he introduced the
fifhes into the veffel in which he had impregnated the water
while it remained inverted in the bafin, the remainder of
the nitrous air not imbibed by the water ftill refting upon
it. The phial contained fomething more that a pint,
and the nitrous air occupied about one fourth of it. Into
this veffel he introduced two fmall fifhes, and they con-
tinued very quiet, without being feized with any convul-
fions (as happened before), ten minutes, or a quarter of
an hour, before they died. Hence, the caufe of the con-
vulfions, in the former experiment, arofe not from the
nitrous air, properly fpeaking, but *nitrous acid*, which
acted like the fixed air, another kind of acid. Whereas
now the fifhes were no otherwife affected than in water
with phlogifticated or inflammable air, except that the
water had imbibed more of the nitrous air, and hence was
fooner fatal to them.

Brouffonet.   From the conformation of the organs of refpiration, or
the gills, in thefe animals, Brouffonet has formed them
into two divifions : *viz.* the cartilaginous, fuch as the
fea-dog, the fhark ; and the fpinous, as the fea-wolf, &c.
In the firft divifion, the gills are fuftained by a cartilagi-
nous arch, and are more confiderable in number than in
the fecond; in the laft, they are fupported by feveral
fmall curved bones, the number being feldom lefs than
four, and never exceeding it.

The ftructure of the gills is fo formed, that the fan-
guineous veffels, which are diftributed over them, make,
as in the lungs of quadrupeds, a very long paffage in a
fhort fpace ; but they differ very much in different kinds
of fifhes. The way of life to which nature has deftined

thefe animals is the principal caufe of thefe varieties, which rarely take place in the refpiratory organs of different quadrupeds and birds. Thus fifhes which live in ftill water, and in places where the water is rarely renewed, fuch as eels, have their gills fuftained by fhort offeous arches; the cavity of their gills is very large, and they are able to preferve the water in thefe organs a much longer time than other fifhes. They may in fome meafure be compared to the reptiles and oviparous quadrupeds, which have cellular lungs furnifhed with fibres, and in fuch a manner as to be able to keep a certain quantity of air in referve in cafe of need. On the contrary, in thofe fpecies of fifhes that frequent the high feas, and are deftined to make long emigrations, and fwim very rapidly, the gills are placed upon very great bones; feveral are provided with a peculiar organ, deftined like the gills for refpiration.

In animals that refpire air there is only one aperture by which this element is received and rejected: this is not the cafe in fifhes which receive water into their refpiratory organs by different ways: thus, in the lamprey there is only one opening at the fummit of the head, by which the water is conducted to the gills; in the ray there is one on each fide of the head; whilft the greater number of fifhes receive water by their mouth, and it departs by the gills. In the cartilaginous fifhes, whofe organs of refpiration, as has been obferved, are more extenfive than thofe of other fifhes, the greateft part reject the water by feveral openings; as in the lampreys, which have feven holes; the fea-dog has five, and the fturgeon has only one, forming feveral divifions. The other fpecies of fifhes have only one opening, but it's form varies according to the animal œconomy of each kind. Thus, thofe deftined to live in fhallow waters and never at a diftance from the banks, and fometimes buried in the fand, have this opening very fmall,

forming a species of canal surrounded by thick membranes. Those which are obliged to make rapid motions have their gills, on the contrary, the most extensively formed ; their mouth and the opening of the gills are very large ; they receive a great quantity of water, and renew it much oftener than the others ; they die almost as soon as they are out of the water : whilst carp, eels, &c. which have small openings, live a long time in the open air. On comparing the respiration of fishes with that of animals that breathe in the open air, it appears, that the first more frequently inspire than the last ; because the oxygen to be extracted from the water is much less abundant than in the atmosphere, and it is more difficultly separated from the water. Fishes, however, appear to have the advantage of a reservoir, which serves occasionally to supply the deficiency of oxygen by the respiratory organs. This is called the air-bladder of fishes. According to the experiments on the air which this bladder contains, by Brodbelt of Jamaica, particularly that of the sword-fish, it is pure oxygen gas : he thinks it serves the purposes of life when the animal is unable to come to the surface. Accum says the air-bladder of a carp contains common air. Monro had supposed it to contain fixed air. Fourcroy says it is azot gas united sometimes with a little carbonic acid gas ; that it is produced in the stomach, and thence passes into this airy *receptacle*. Fishes are not able to support in water a degree of heat equal to that which man and quadrupeds support in the atmosphere, and the difference is very considerable. On making the comparison, physicians have observed, that air may be breathed by the human species at 264° with impunity. Tillet made animals breathe an air heated to 300°. A girl, likewise, under Marantin, breathed an air of 325° for five minutes. Notwithstanding such degrees of heat would be insupportable to fishes, and would even be sufficient to

Air-bladder of fishes.

deſtroy their organization, ſeveral obſervations have been
made on fiſhes found alive in very warm waters, and even
by the ancients. Thus Ælian ſpeaks of a lake in Libya,
the water of which is very warm, and fiſhes are found in
it which die if tranſported to a colder water. Similar ob-
ſervations are to be found in St. Auguſtin and Cardanus.
Shaw, in his voyage to Barbary, ſpeaks of ſeveral hot
waters in which he had found ſeveral ſpecies of perch;
and des Fontaines lately made the ſame obſervation in the
neighbourhood of Cafza, where the thermometer of R.
roſe to 30°. Lucas, in his Hiſtory of Mineral Waters,
gives ſome obſervations on living carp found in a thermal
water, the heat of which was equal to that of the human
blood. Valiſnieri and Conringius have likewiſe ſeen liv-
ing fiſhes in thermal waters. Anderſon witneſſed a ſimi-
lar fact in Iceland. But the moſt ſurpriſing fact is that
of Sonneret, who found ſome fiſhes in a water at the
Manillas at the degree of 69 of Reaumur. From the ex-
periments of Brouſſonet, fiſhes did not live at ſo high a
temperature. Muſchenbroek had already found that
fiſhes periſhed at 111° of Fahrenheit; he even ſaw a very
vigorous perch die in three minutes in a water heated to
96°. He adds, that theſe animals lived very well at 72°.
It is very difficult to determine, in a poſitive manner, the
different degrees of heat each ſpecies is able to bear; they
differ not only according to the ſeaſon, but likewiſe ac-
cording to the forms of the organs of reſpiration.

On the 20th of June, 1784, Brouſſonet put a couple of
ten-ſpined ſtickle-backs (epinoches) into ſome water at
a temperature of 14°. This was gradually heated, and at
the end of two hours and a half the thermometer mounted
to 28°: the fiſhes then became agitated, but on being caſt
into freſh water they became well again in a few minutes.

On the 10th of November, 1784, he put a carp, ſome
bleaks, gudgeons, and perch, into ſome water of the Seine

at 5°, and the bottom of the veffel was covered with fand. At 25 minutes paft twelve o'clock the thermometer was at 6½° ; at 30 minutes at 8°, &c. This experiment lafted till 45 minutes paft four ; and he marked the degrees of heat every five minntes, pouring fome frefh water into the veffel at different times in fmall quantities. At 12°, the fmalleft fifhes began to rife to the furface of the water, became agitated and ill; yet the Seine water is much warmer in the fummer. At 21° the fmall bleaks were nearly dead. At 22° the perch were motionlefs, and reverfed. The gudgeons, which were of a larger fize, did not appear to fuffer till 23° ; whilft the carp was not at all agitated, it's refpiration being only more frequent. At 28°, at which point the water was kept 15 minutes, the carp began to lofe it's equilibrium, and became ill ; it afterwards appeared dead, and only came to itfelf again after being left a long time in frefh water. Brouffonet employed four hours and a half in bringing the heat of the water to 28°. He is of opinion that, with certain precautions, fifh would live in a water-heated beyond 28°.

" On fuppofing," fays Brouffonet, " as I have reafon " to believe from my experiments, that fifhes cannot fup- " port water heated beyond 30° ; on recollecting, at the " fame time, that it is impoffible for them to live in a wa- " ter the temperature of which is a few degrees below zero, " it would follow that thefe animals could only live in a " feale of 30 degrees at moft ; a feale which, when com- " pared with that fupported by warm-blooded animals, " will appear very fhort : it will, however, always be in " a ratio to the vital heat, which in fifhes is even below " that of reptiles and oviparous quadrupeds. Martine has " obferved of feveral falt-water fifhes, that the heat of " their blood did not exceed the water in which they " were, more than one degree. The fame experiment re-

" repeated upon a trout, and other river-fish, afforded him
" the fame refult. Mr. John Hunter faw the thermome-
" ter in the ftomach of a carp rife from $65\frac{1}{2}°$, which was
" the temperature of the water, to $69°$, i. e. three degrees
" and a half higher : but it is neceffary to obferve that
" the fifh was then out of the water ; which muft have a
" great influence on the refult of the experiment."

Brouffonet plunged a thermometer into the bodies of
feveral fmall fifhes of the Seine, which never rofe higher
than three fourths of a degree beyond the temperature of
the water ; fometimes it only increafed half a degree, par-
ticularly in thofe that were ill. A pretty large eel, although
weak, only caufed the thermometer to rife three fourths
of a degree. Carp conftantly gave one degree more,
fome a degree and a half; fo that it appears the animal
heat of fifhes is very inconfiderable.

According to the fame author, fifhes are fubject to a
great lofs of animal heat by the water continually extract-
ing it ; fo that the portion of this fluid immediately fur-
rounding them is warmer than elfewhere. It has been
obferved, that a carp plunged into a mixture that foon
became congealed, preferved around it a certain quantity
of fluid water, although the reft was totally congealed.

The animal heat of fifhes, no doubt, arifes from
their refpiration ; for the phenomena by which Lavoifier
and de la Place have explained it's production in animals
living in the atmofphere, are obferved alfo in fifhes, but in
a lefs evident degree : the difference of heat between ani-
mals breathing air, and thofe which refpire water, is
more particularly remarkable on comparing fifhes with
the cetaceous order. Both inhabit the fame element ; yet
thofe with gills, that refpire water, have only one degree
or one and a half more than the water itfelf, whilft the
cetaceous order that refpire air have their blood as warm
as man. Brouffonet found the body of a porpoife

juſt dead to be 28½° in the neck, whilſt the temperature of
the atmoſphere was at 14°, and that of the ſea-water near
the ſhore at 13½°.

It alſo appears that fiſhes do not ſuffer ſuch extreme va-
riations of cold and heat as quadrupeds. The tempera-
ture of the water, at a certain depth, is almoſt always
the ſame, as appears, with reſpect to the ſea, from the ex-
periments of Marſili and Sauſſure. That of rivers, when
the ſurface is frozen, is a few degrees above zero in
the middle. In great heats, the temperature of the water
is always below that of the air. Yet it appears that theſe
animals are more ſenſible to a great degree of heat than
of cold.

Fiſhes are, however, affected by the variations of the
atmoſphere; and it is to it's great variations in tempera-
ture that the emigration of that prodigious quantity of her-
rings is to be attributed, which the cold of the pole forces
annually to ſeek more temperate ſeas. Fiſhes likewiſe
which live near the banks, feel the cold of the air, and go
into deeper places to protect them from it, where the
greater part remain in a ſtate of torpidity, ſimilar to what
bears, marmots, and dormice undergo during the winter.
The ancients have given ſome account of this periodical
ſleep, whilſt the moderns have ſcarcely obſerved it. The
fiſhes of this order may be, however, known by the great
length of their body, the abſence of the ventral fins, and
the undulating motions they are obliged to make to ſup-
port themſelves in the water.

It is obſerved that water affects the organs of reſpira-
tion in fiſhes, in a greater variety of ways than air acts
upon thoſe of warm-blooded animals. Several individu-
als, after having reſpired a certain quantity of water for
ſome time, vitiate it ſo much as to be no longer proper for
reſpiration, in the ſame manner as warm-blooded animals
change the air. Water, likewiſe, holds in ſolution a

greater number of fubftances than the air; and amongft thefe many are found to be prejudicial to fifhes, by acting on their refpiratory organs, which more rarely happens to animals living in the atmofphere. They are able, however, to refift fome of thefe changes: thus, they pafs from falt to fweet waters, and reciprocally, without detriment; numbers of falmon, fhads, lampreys, &c. annually leave the fea and mount the frefh water rivers, whilft the carp often quits the river for the faltnefs of the ocean. Brouffonet found that fifhes are able to live in diftilled water; that they at firft fhowed figns of uneafinefs, but after fwimming about for fome time they no longer appeared to fuffer; he thinks it moft probable, that by moving about they had caufed the water to unite with a quantity of air fufficient for refpiration. He, however, found that a fmall fifh enclofed in a corked bottle containing a pint of diftilled water, lived more than thirty hours. He found that a fmall quantity of firup of violets, dropped into the diftilled water in which were living fifhes, at firft underwent no change of colour: it became fomewhat green afterwards, arifing perhaps from the alkali of the mucus with which they are covered, and which always mixes with the water. A drop of acid of arfenic in a large quantity of water immediately killed a very ftrong fifh. Water flightly impregnated with fixed air deftroyed a fimilar fifh in a few minutes. Plunged into lime water they likewife very foon died. It was well known that by throwing lime into water fifhermen are accuftomed to deftroy the fifhes; and by feveral other fubftances the fame is effected. Thus, in the Indies the juices of feveral fpecies of plants are made ufe of. In the fouth of France the milky juice of the *euphorbia characias* of Linnæus, which grows there in great abundance in uncultivated places, is employed for the fame purpofe. It is by affecting the

respiratory organs of these animals that their death is oc-
casioned.

We are informed by Bell (in contradiction to what
Brouffonet has said), that if there be no air in the water
in which fishes are, or not in sufficient quantity for them
to breathe, they die; that distilled water is to these ani-
mals what the vacuum of an air-pump is to an animal
that respires air in the atmosphere; that if you exhaust
water of it's air by a pump, or boil or distil it, or by any
other means deprive it of it's air, fishes are no longer able
to breathe in it; that they rise to the surface and gasp for
air; and that on extracting the air from water in which
fishes have respired, it is found to be contaminated exactly
in the same manner as air respired by warm-blooded ani-
mals; and that it differs very little from that in which a
candle has spontaneously become extinguished; which,
according to this author, are sufficient facts to prove that
the gills of these animals perform the same functions of a
real respiration as the lungs of a man and quadrupeds,
which extract the oxygen from the atmosphere.

For more satisfactory information respecting the respi-

ration of fishes, we are indebted to Davy; for, as it has
been supposed that fishes decompose both water and oxy-
gen gas, he made the following experiments to ascertain
the truth.

1st Experiment. He expelled, by long boiling, the
atmospheric air from 64 cubic inches of sea-water: he
then excluded it from the air by means of mercury.
Having then introduced a small mullet, it was instantly
convulsed, and died in a few minutes.

2d Experiment. A quantity of water was freed, by
boiling, of it's atmospheric air: two receivers, each of
the capacity of 36 cubic inches, were filled with this
water: into one of these two cubic inches of nitrogen

were introduced, into the other two of phos-oxygen. By long and conftant agitation the gafes were diffolved by the water, which was excluded from the contact of air by mercury. Into each of the receivers two minnows were introduced. Thofe in the water holding nitrogen in folution died in about four minutes, thofe in the water holding phos-oxygen, in folution appeared totally uninjured, and when examined, after fome hours, were ftill alive and healthy.

3d Experiment. The fame receivers ufed in the laft experiment were filled with diftilled water freed from atmofpheric air by a fecond boiling. Into each of thefe, three cubic inches of phos-oxygen were introduced. The receivers were then agitated for fome time, till the water in each of them had diffolved an equal quantity of gas; they were then inverted in a trough of mercury, fo as to exclude atmofpheric air from them. Four minnows were then conveyed into one of them through mercury. The receivers were now fuffered to remain untouched for fix hours, when they were examined. The minnows were alive, and no gas remained in the top of the receiver in which they had refpired. The gas in the top of the other receiver remained nearly the fame as at the commencement of the experiment. A quantity of lime-water was poured into each of thefe receivers; in that in which the fifhes had exifted there was a very perceptible cloudinefs, occafioned, as Davy fuppofed, by the formation of carbonat of lime; in the other there was no perceptible change.

From thefe experiments Davy concludes, that the venous blood in the gills of fifhes is phos-oxydated by the phos-oxygen held in folution by water; and that carbonic acid, and probably water, are given out as excrementitious by the venous blood in their gills. With refpect to the decompofition of water by fifhes in refpiration, as there is

no evidence of hydrogen being formed, there can be no reason for the supposition.

Respiration of Insects.—From the much greater length of time insects are capable of existing than other animals in carbonic acid gas, and, according to Dr. Priestley, in air infected by putrid effluvia, it had been supposed by some physiologists that this class of animals either had the power of living a certain time without breathing, or that they had not the same occasion for it as others whose respiration is well understood. It had not been considered, that as insects, from their habits of life, are accustomed to live in places where the air is in a state of great impurity, they would not be so liable to experience it's bad effects, as those who constantly breathe a purer atmosphere: nor was it well understood by what means this function was carried on in this most numerous part of the animal kingdom.

Scheele and Bergman.

It was, indeed, a fact acknowledged by Scheele and Bergman, that insects, the same as other animals, converted vital air into mephitic gas by the act of respiration; but no experiments of any consequence had taken place on this subject before those of Vauquelin, at least they were by no means so satisfactory. It is now well known that the function of respiration is not performed by the mouth of insects, by which they differ very much from warm-blooded animals, and that they have not like them a pulmonary organ into which the blood passes to receive the influence of the air from the atmosphere.

It is now well understood, that insects take in this element by means of certain openings or holes, to which entomologists have given the name of stigmata, from their resemblance to so many spots on the surface of their body. These stigmata are of various forms; sometimes they are round, sometimes oval, but in general they are lengthened

like a button-hole. With refpect to the number, it varies according to the nature and fize of the animal.

The experiments of Vauquelin were made on the grafs- Vauquelin.
hopper (gryllus viridiffimus), the red flug (limax flavus), and the fnail (helix pomalia of Linnæus). The *grafs-hopper* has 24 ftigmata difpofed in four rows, parallel and exterior to the two white lines placed longitudinally on the middle of it's belly, and the motions of infpiration and expiration are well marked. Vauquelin found that this animal died immediately on being put into fulphureous hydrogenous gas. In fix cubic inches of pure air it exifted 18 hours, and in eight of common air 36 hours: he found that oxygen gas was indifpenfably neceffary to the life of this infect; that as foon as there no longer remains any or very little of this gas in the atmofpheric air, it immediately dies. The atmofpheric air in which feveral had died was found to contain fcarcely any remnant of oxygen gas: but whatever number were fuffered to breathe until their complete afphixy, it was not obferved that they had entirely converted the vital air into carbonic acid; they appeared conftantly to die before this conver-fion was complete. He attributes this to the fenfibility of the animal for the carbonic acid gas, which deftroys it when in large proportion as well as azot gas.

The refpiratory organs of the *red flug* have not as yet been difcovered by anatomifts; but Vauquelin looks upon them to be the lateral openings of this animal, which are feen to dilate and contract. This flug, on being put into 12 cubic inches of atmofpherical air, died in 48 hours; and not the leaft appearance of oxygen gas was found afterwards, the remaining air precipitating lime water; which proves that it was entirely converted into fixed air. This chemift was much aftonifhed to find how completely this animal had analyfed the atmofpherical air, having never difcovered the leaft trace of vital air in the refiduum

of that refpired, when examined by means of phofphorus.
" Hence," fays he, " it appears that worms have in their
" refpiratory organs a great power of feparating the
" oxygen gas from the particles of azot gas with which
" it is on all fides furrounded, and that they have no oc-
" cafion for a large quantity of oxygen at one time; that
" they are able to remain for fome time without refpi-
" ring in the ordinary way; and, thirdly, that they are
" not very fenfible to the influence of carbonic acid gas
" formed in the refpired atmofpherical air, and of the azot
" gas left naked." A flug confumed in 48 hours 3.36
inches of oxygen gas, when it immediately rolled itfelf
up, emitting from all parts a milky liquor, and died.

In fulphureous hydrogenous gas a flug fhowed no figns
of life in about half an hour; which proves that worms
cannot exift in an elaftic fluid containing no oxygen gas,
although of all animals they appear from their manners
of life to have the leaft occafion for it.

With refpect to the laft animal, the *fnail*, it lived four
days in 12 cubic inches of atmofpherical air. The oxy-
gen of this air was found to be entirely abforbed, or
deprived of it's natural principle; for the azot gas re-
maining did not contain an atom of it, the refiduum like-
wife contained carbonic acid. That the death of this
animal was owing to the want of oxygen, and not to the
want of food, he proved by finding that others of the
fame fpecies were able to live feveral months without any
food.

From thefe experiments it appears,

1ft. That infects and worms refpire oxygen gas like
warm blooded animals, and that like them they convert it
into water and carbonic acid.

2d. That this principle is abfolutely neceffary in their
refpiration, and that they die when deprived of it.

3d. That every other elaftic fluid, except oxygen gas, is unfit for their refpiration.

4th. That worms, and particularly the red flug and the efculent fnail, appear to have very extraordinary refpiratory powers, and very little fenfibility for the prefence of carbonic acid, fince they feparate all the vital air from the azot gas, and from the carbonic acid which is formed; and that they only perifh when there no longer remains any oxygen gas.

5th. That this property, Vauquelin thinks, may render thefe laft animals very ufeful as an eudiometer, by offering a proper means of exactly feparating the oxygen gas from the azot gas, and confequently of affording a perfect knowledge of the proportions of the principles of the atmofpherical air, or of a vital air, the degree of purity of which may be required.

Davy has difcovered, by experiments fimilar to thofe Davy. made upon fifhes, that the zoophytes have their refpiration governed by fimilar laws; that they, like fifhes, abforb the phos-oxygen held in folution by water, as well as portions of nitrogen; and thus, in their chemical attractions as well as in their organic powers, they feem to form the connecting links between animals and vegetables.

There now remains to give an account of the experiments and conclufions of this laft author on the nitrous oxyd, and fome other gafes, which he made upon himfelf and various animals, forming a curious mafs of information.

This ingenious experimentalift begins by explaining the word *refpirable*; which term he employs to denote thofe gafes capable of being taken into the lungs by voluntary efforts. On the contrary, *nonrefpirable* gafes, when applied to the external organs of refpiration, ftimulate the mufcles of the epiglottis in fuch a way, as to keep it perfectly clofe on the glottis, which prevents the fmalleft

particle of gas from entering into the bronchia, in fpite
of voluntary exertions. One only has the power of uni-
formly fupporting life—atmofpheric air. Other gafes,
when refpired, fooner or later produce death, but in
different modes. Some, as nitrogen and hydrogen, effect
no pofitive change in the venous blood. Animals im-
merfed in thefe gafes die of a difeafe produced by privation
of atmofpheric air, analogous to that occafioned by their
fubmerfion in water or nonrefpirable gafes. Others, as
the different varieties of hydrocarbonat, deftroy life by
producing fome pofitive change in the blood, which pro-
bably immediately renders it incapable of fupplying the
nervous and mufcular fibres with principles effential to
fenfibility and irritability. Oxygen, which is capable of
being refpired for a much greater length of time than any
other gas, except common air, finally deftroy life; firft
producing changes in the blood, connected with new
living action.

In making his experiments, Davy made ufe of a large
mercurial air-holder, the invention of Clayfield: in it's
form it is analogous to Watt's hydraulic bellows, confift-
ing of a glafs bell playing under the preffure of the atmo-
fphere, in a fpace between two cylinders filled with mer-
cury. The inftrument was graduated to the cubic inch
of Everard, and furnifhed with a ftop-cock.

To afcertain the changes effected by refpiration, the
ftop-cock having a very large orifice, curved and flattened
at it's upper extremity, formed an air-tight mouth-piece.
By accurately clofing the nofe, and bringing the lips tight
on this mouth-piece, after a few trials, he was able to
breathe oxygen or common air for two minutes or two
minutes and a half, without any other uneafy feeling than
that produced by the inclination of the neck and cheft to-
wards the cylinder: but the power of uniformly exhauft-
ing the lungs and fauces to the fame extent, required a

longer time. At laſt, by preſerving exactly the ſame poſture, after exhauſtion of the lungs before the inſpiration of the gas to be experimented upon, and during it's complete expiration, he found he could always retain nearly the ſame quantity of gas in the bronchial veſſels and fauces, the difference in the volume expired at different times never amounting to a cubic inch and half.

By connecting the conducting pipe of the air holder, during the reſpiration of the gas, with a ſmall trough of mercury by means of a curved tube, it became a perfect and excellent breathing machine: for, by exerting a certain preſſure on the air holding cylinder, it was eaſy to throw a quantity of gas, after every inſpiration or expiration, into tubes filled with mercury ſtanding in the trough. In theſe tubes it could be accurately analyſed, and thus the changes taking place at different periods of the proceſs aſcertained.

Davy was firſt induced to the examination of this gas, Nitrous or the dephlogiſticated nitrous gas of Dr. Prieſtley, from oxyd. Mitchill's Theory of Contagion, which is looked upon by the experimentaliſt as fallacious. In 1799 he began the inveſtigation : but a conſiderable time elapſed before he was able to procure the gas in a ſtate of purity, and his firſt experiments were made on the mixtures of nitrous oxyd, nitrogen, and nitrous gas, which are produced during metallic ſolutions. Dr. Mitchill attempted to prove that this gas, which he calls oxyd of ſepton, is the principle of contagion (vide art. Miaſmata), and capable of producing the moſt terrible effects when reſpired by animals in the minuteſt quantities, or even when applied to the ſkin or muſcular fibre. Davy, however, on making a few coarſe experiments on ſmall quantities of the gas procured from zinc and diluted nitrous acid, found that wounds were expoſed to it's action, and the bodies of animals immerſed in it, without injury ; and that he was

able to breathe it, but with remarkable effects. He often breathed a quart of it, or even two quarts, mingled with more than equal parts of oxygen or common air. In the moft decifive of thefe trials, it's effects appeared to be depreffing, and he imagined it produced a tendency to fainting; the pulfe was rendered flower under it's operation. He then infpired the pure gas; and as it paffed through the bronchia without ftimulating the glottis, and produced no uneafy feeling in the lungs, it proved the nitrous oxyd to be refpirable.

Method of procuring it.

The pure nitrous oxyd was procured by the decompofition of nitrat of ammonia, in a temperature not exceeding 440°. 200 grains of compact nitrat of ammonia were introduced into a glafs retort, and decompofed flowly by the heat of a fpirit lamp. The firft portions were rejected, and the laft received in jars containing mercury. This gas, when collected, exhibited the following properties:

It's properties.

a. A candle burnt in it with a brilliant flame and crackling noife. Before it's extinction, the white inner flame became furrounded with an exterior blue one.

b. Phofphorus introduced into it in a ftate of inflammation burnt with infinitely greater vividnefs than before.

c. Sulphur introduced into it when burning with a feeble blue flame, was inftantly extinguifhed; but when in a ftate of active inflammation (i. e. forming fulphuric acid) it burnt with a beautiful and vivid rofe coloured flame.

d. Inflamed charcoal deprived of hydrogen introduced into it, burnt with much greater vividnefs than in the atmofphere.

e. Iron burned with great vividnefs, and threw out bright fparks, as in oxygen.

f. Thirty meafures of it expofed to water previoufly

boiled was rapidly abforbed: when the diminution was complete, rather more than a meafure remained.

g. Pure water faturated with it gave it out again on ebullition, and the gas thus produced retained all it's former properties.

h. It was abforbed by red cabbage juice, but no alteration of colour took place.

i. It's tafte was diftinctly fweet, and it's odour flight, but agreeable.

j. It underwent no diminution when mingled with oxygen or nitrous gas.

After the abforption of the nitrous oxyd by water, there remained another gas; on examining which it appeared reafonable to conclude,

1ft. That the refidual gas of nitrous oxyd is air previoufly contained in the water (which in no cafe can be perfectly freed from it by ebullition), and liberated by the ftronger attraction of that fluid for nitrous oxyd.

2d. That nitrat of ammonia at temperatures below 440° is decompounded into pure nitrous oxyd and fluid.

3d. That in afcertaining the purity of nitrous oxyd from it's abforption by water, corrections ought to be made for the quantity of gas difpelled from the water; this quantity in common water diftilled under mercury being about $\frac{1}{50}$th; in water fimply boiled and ufed when hot about $\frac{1}{30}$th, and in common fpring water $\frac{1}{12}$th.

It's fpecific gravity; accounting for the fmall quantity of common air contained in it (90 cubic inches of it containing about $\frac{1}{15}$th of common air, introduced from the mercurial air holder into an exhaufted globe, which increafed it in weight 44.75 grains, the thermometer being 50° and atmofpheric preffure 30.7); was concluded to be fuch, that 100 cubic inches weigh 50.1 grains at temperature 50°, and at atmofpheric preffure 37. *It's fpecific gravity.*

It is compofed of oxygen and nitrogen; for, drawing
conclufions from the quantity of carbonic acid formed,
2.5 grains of nitrous oxyd are compofed of .82 oxygen,
and 1.68 nitrogen; or 100 grains of nitrous oxyd contain
37 of oxygen, and 63 of nitrogen. On making expe-
riments on the refpiration of nitrous oxyd by warm
blooded animals, it was procured as above related, and
received in large jars filled with water previoufly faturated
with the gas. The animal was introduced into the jar by
being carried under the water, by which it fuffers little
or nothing: after it's introduction, the jar was made to
reft on a fhelf about half an inch below the furface of the
water, and the animal carefully fupported fo as to prevent
it's mouth from refting in the water. The animals ex-
perimented upon were the cat, dog, rabbit, guinea pig,
moufe, and goldfinch.

In each of thefe experiments a certain abforption of
the gas was always perceived, the water rifing in the jar
during the refpiration of the animal. From thefe it ap-
pears,

1ft. That nitrous oxyd is deftructive, when refpired for
a certain time, to the warm blooded animals, apparently
previoufly exciting them to a great extent.

2d. That when it's operation is ftopped before complete
exhauftion is brought on, the healthy living action is ca-
pable of being gradually reproduced, by enabling the ani-
mal to refpire atmofpheric air.

3d. Exhauftion and death are produced in the fmall
animals by nitrous oxyd fooner than in the larger ones,
and in young animals of the fame fpecies, in a fhorter
time than in old ones.

He found that animals live at leaft twice as long in ni-
trous oxyd as they do in hydrogen or water; confequently,
there was every reafon to fuppofe from this circumftance

alone, that their death in nitrous oxyd could not depend on the fimple privation of atmofpheric air : but that it was owing to fome peculiar changes effected in the blood by the gas.

The external appearance of animals that have been de- On diffec-
ftroyed in nitrous oxyd is very little different from that tion.
of thofe killed by privation of atmofpheric air. The fauces and tongue appear of a dark red, and the eyes are dull and a little protruded. Their internal organs, how- ever, exhibit a very peculiar change : the lungs are a pale brown red, and covered here and there with purple fpots ; the liver is of a very bright red, and the mufcular fibre in general dark. Both the auricles and ventricles of the heart are filled with blood. The auricles contract for minutes after the death of the animal. The blood in the left ventricle and the aorta is of a tinge between purple and red, whilft that in the right ventricle is of a dark co- lour, rather more purple than the venous blood. Thefe appearances are fimilar to thofe obferved by Dr. Beddoes in animals that had been made to breathe oxygen a great length of time.

From other experiments on the refpiration of mixtures of nitrous oxyd and other gafes, and on recapitulating thofe before mentioned, it appears,

1. That warm blooded animals die in nitrous oxyd in- Recapitula-
finitely fooner than in common air or oxygen ; but not tion.
nearly in fo fhort a time as in gafes incapable of effecting pofitive changes in the venous blood, or in nonrefpirable gafes.

2. The larger animals live longer in nitrous oxyd than the fmaller ones, and young animals die in it fooner than old ones of the fame fpecies.

3. When animals, after breathing nitrous oxyd, are removed from it before complete exhauftion has taken

place, they are capable of being reſtored to health under the action of atmoſpheric air.

4. Peculiar changes are effected in the organs of animals by the reſpiration of nitrous oxyd. In animals deſtroyed by it, the arterial blood is purple red, the lungs are covered with purple ſpots, both the hollow and compact muſcles are *apparently* very irritable, and the brain is dark coloured.

5. Animals are deſtroyed by the reſpiration of mixtures of nitrous oxyd and hydrogen, nearly in the ſame time as by pure nitrous oxyd : they are capable of living for a great length of time in nitrous oxyd, mingled with very minute quantities of oxygen or common air.

Amphibious animals. As it appeared that the nitrous oxyd deſtroyed warm blooded animals, by increaſing the living action of their organs to ſuch an extent as finally to exhauſt their irritability and ſenſibility ; it was reaſonable to conjecture that the cold blooded animals, poſſeſſed of voluntary power over reſpiration, would ſo regulate the quantity of nitrous oxyd applied to the blood in their lungs, as to bear it's action for a great length of time. But this conjecture, on experiment, was found to be erroneous.

From the experiments upon them, it appears that water lizards, and moſt probably the other amphibious animals, die in nitrous oxyd in a much ſhorter time than in hydrogen, or pure water; conſequently, their death in it cannot depend on the ſimple privation of atmoſpheric air.

Fiſhes. It was expected that fiſhes, like amphibious animals, would have been very quickly deſtroyed by the action of nitrous oxyd ; but although water ſaturated with nitrous oxyd had no poſitive effects upon them, they ought, according to Davy, to die in it much ſooner than in water deprived of air by ebullition. From their living in it rather longer, it may be concluded, that they are de-

ftroyed not by privation of atmofpheric air, but from fome pofitive change effected in their blood by the gas.

He had long ago obferved, that the gills of fifhes became rather of a lighter red during their death in the atmofphere, and conjectured that the difeafe of which they died was probably hyperoxygenation of the blood connected with highly increafed animal heat. For not only is oxygen prefented to their blood in much larger quantities in atmofpheric air than in it's aqueous folution, but like-wife in a ftate in which it contains, to ufe common language, much more *latent heat*. Without, however, laying any ftrefs on this fuppofition, he had the curiofity to try whether thornbacks would live longeft in atmofpheric air or nitrous oxyd. In one experiment they appeared to die in them nearly in the fame time. In another, the fifh in nitrous oxyd lived nearly half as long again as that in atmofpheric air. The winged infects fur- Infects. nifhed with breathing holes became motionlefs in nitrous oxyd very fpeedily : being, however, poffeffed of a certain voluntary power over refpiration, they fometimes recover, after having been expofed to it for fome minutes, under the action of atmofpheric air. A butterfly died in nitrous oxyd in fix minutes ; in hydrogen, in five minutes. A large fly became motionlefs in nitrous oxyd in half a minute ; in hydrogen, in a quarter of a minute ; in hydro-carbonat it dropped immediately fenfelefs. Flies live much longer under water, alcohol, or oil, than in non-refpirable gafes, or gafes incapable of fupporting life. A certain quantity of air always continues attached in the fluid to the fine hairs furrounding their breathing holes, fufficient to fupport life for a fhort time.

Snails and earth worms live in nitrous oxyd a long Snails and while ; they die in it, however, much fooner than in wa- earth worms. ter or hydrogen, probably from the fame caufes as amphibious animals.

Having difcovered that the nitrous oxyd was refpirable, the next thing was to inveftigate the changes effected in it by the venous blood; and finding that the refidual gas of nitrous oxyd, after it had been breathed for fome time in filk bags, was chiefly nitrogen, the conjecture at firft was, that the nitrous oxyd was decompofed in refpiration in the fame manner as atmofpheric air, and it's oxygen only combined with the venous blood : but experiments proved the contrary ; for it was found,

It's effects on venous blood.

1ft. That when nitrous oxyd is agitated in fluid venous blood, a certain portion of the gas is abforbed, whilft the colour of the blood changes from dark red to red purple.

2d. That during the abforption of nitrous oxyd by the venous blood, minute portions of nitrogen and carbonic acid are produced, either by evolution from the blood, or from a decompofition of part of the nitrous oxyd.

3d. That venous blood impregnated with nitrous oxyd is capable of oxygenation; and, *vice verfa,* that oxygenated blood may be combined with nitrous oxyd.

Changes in the nitrous oxyd by refpiration.

To afcertain accurately the changes effected in nitrous oxyd by refpiration, a large mercurial air holder of the capacity of 200 cubic inches was ufed. Whenever the pure nitrous oxyd was breathed after a complete voluntary exhauftion of the lungs, the pleafurable delirium was rapidly produced ; and being obliged to ftoop on the cylinder, the determination of blood to the head from the increafed arterial action in lefs than a minute became fo great, as often to deprive the experimentalift of voluntary power over the mufcles of the mouth. Hence he could never rely on the accuracy of any experiment in which the gas had been refpired for more than three fourths of a minute. He was able to refpire the gas with great accuracy for more than half a minute ; and in all his experiments on the refpiration of this nitrous oxyd, a very confiderable diminution of gas always took place, and the

diminution was in general apparently greater to the eye during the firſt four or five inſpirations.

The reſidual gas of an experiment was always exa- The reſidual gas how examined. mined as follows: After being transferred through mercury into a graduated cylinder, a ſmall quantity of concentrated ſolution of cauſtic potaſh was intoduced into it, where it remained in contact ſome hours: the diminution was then noted, and the quantity of gas abſorbed by the potaſh judged to be carbonic acid. To the remainder twice it's bulk of pure water was admitted; and, after agitation and reſt for four or five hours the abſorption was noticed, and the gas abſorbed confidered as nitrous oxyd. The reſidual unabſorbable gas was mingled over water with twice it's bulk of nitrous gas; and by theſe means it's compoſition, whether it confiſted wholly of nitrogen, or of nitrogen mingled with ſmall quantities of oxygen, aſcertained.

From a number of experiments, the following are ſelected as the moſt accurate on the reſpiration of nitrous oxyd:

1. At temperature 54°, 102 inches of nitrous oxyd were breathed, which contained nearly $\frac{1}{5}$th common air, for about half a minute, ſeven inſpirations and ſeven expirations being made. After every expiration an evident diminution of gas was perceived; and on the laſt full expiration it filled a ſpace equal to 62 cubic inches.

Theſe 62, being analyſed, were found to confiſt of

Carbonic acid 3.2
Nitrous oxyd 29.0
Oxygen 4.1
Nitrogen 25.7

62.0

Hence, accounting for the two cubic inches of common

air previoufly mingled with the nitrous oxyd, 71 cubic inches had difappeared.

2. At temperature 47°, 132 were breathed, with $2\frac{1}{2}$ of atmofpheric air of the air holder, for 40 feconds—in all eight refpirations. The gas after the laft expiration equalled 128 cubic inches, which, on analyfis, confifted of

$$
\begin{array}{ll}
\text{Carbonic acid} & \text{....} \quad 5.25 \\
\text{Nitrous oxyd} & \text{......} \quad 88.75 \\
\text{Oxygen} & \text{.........} \quad 5.00 \\
\text{Nitrogen} & \text{........} \quad 29.00
\end{array}
$$

Confequently 93.25 cubic inches had difappeared in this experiment. Hence nitrous oxyd is rapidly abforbed by the venous blood through the moift coats of the pulmonary veins. But as, after a complete voluntary exhauftion of the lungs, much refidual air muft remain in the bronchial veffels and fauces, as appears from their incapability of completely collapfing, it is evident that the gas expired after every infpiration of nitrous oxyd muft be mingled with different quantities of the refidual gas of the lungs ; and after a complete expiration, much of the unabforbed nitrous oxyd muft remain as refidual gas in the lungs. Now, when a complete expiration is made after the breathing of atmofpheric air, it is evident that the refidual gas of the lungs confifts of nitrogen mingled with fmall portions of oxygen and carbonic acid, becaufe thefe products are formed during the refpiration of common air, and they are the only products found after the refpiration of nitrous oxyd.

To afcertain whether thefe products were partly produced during the procefs of refpiration, or whether they were wholly the refidual gafes of the lungs, was found extremely difficult. The firft, however, is the moft probable.

For this purpofe the author firft thought of breathing nitrous oxyd immediately after his lungs had been filled

with oxygen, and to compare the products remaining after the full expiration with thofe produced after a full expiration of pure oxygen; but this idea was relinquifhed. He attempted to infpire nitrous oxyd, after having made two infpirations, and a complete expiration of hydrogen; but the effects of the hydrogen were fo debilitating, and the confequent ftimulation by the nitrous oxyd fo great, as to deprive him of fenfe.

Though experiments on fucceffive infpirations of pure nitrous oxyd might go fo far as to determine whether or no any nitrogen, carbonic acid, and oxygen were products of refpiration; yet he diftinctly faw that it was impoffible in this way to afcertain their quantities, fuppofing them produced, unlefs he could firft determine the capacity of his lungs, and the different proportions of the gafes remaining in the bronchial veffels after a complete expiration, when atmofpheric air had been refpired. In fome experiments (made on the refpiration of hydrogen, to determine whether carbonic acid was *produced* by the combination of carbon loofely combined in the venous blood with the oxygen refpired, or whether it was fimply *given out* as excrementitious by this blood) he found, without being able to refolve the problem, that in the refpiration of pure hydrogen, little or no alteration of volume took place; and that the refidual gas was mingled with fome nitrogen, and a little oxygen and carbonic acid.

From the comparifon of thefe facts with thofe on the abforption of nitrous oxyd by venous blood, and on the effects produced upon animals by the refpiration of nitrous oxyd, there was every reafon to fuppofe that hydrogen was not abforbed or altered, when refpired, but only mingled with the refidual gafes of the lungs.

Hence, by making a full expiration of atmofpheric air, and afterwards taking fix or feven refpirations of hydrogen in the mercurial air-holder, and then making

a complete expiration, he thought that the refidual gas and the hydrogen would be fo mingled, as that nearly the fame proportions fhould remain in the bronchial veffels as in the air-holder. By afcertaining thefe proportions, and calculating from them, he hoped to be able to afcertain with tolerable exactnefs the capacity of his fauces and bronchia, as well as the compofition of the gas remaining in them, after a complete expiration of common air.

<div style="margin-left:2em; font-size:smaller">To afcertain the capacity of the fauces and bronchia, and the compofition of the gas remaining in them.</div>

Hydrogen.—The hydrogen employed for this purpofe was procured from the decompofition of water by means of clean iron filings and diluted fulphuric and muriatic acids. It was breathed in the fame manner as nitrous oxyd, in the large mercurial air-holder. The difficulty of making the experiments was great, from the difficulty of breathing hydrogen for half a minute fo as to make a complete expiration of it, after a complete voluntary exhauftion of the lungs. The purity of the hydrogen was afcertained immediately before the experiment by the teft of nitrous gas, and by detonation with oxygen in atmofpheric air: generally 12 meafures of atmofpheric air were fired with four of the hydrogen; and if the diminution was to ten or a little more, the gas was judged pure. After the experiment, when the complete expiration had been made, and the common temperature reftored, the volume of the gas was noticed, and then a fmall quantity of it thrown into the mercurial apparatus, by means of the conducting tube, to be examined. The carbonic acid was feparated by folution of potafh or ftrontian; the quantity of oxygen afcertained by nitrous gas of known compofition; the fuperabundant nitrous gas was abforbed by a folution of muriat of iron; and the proportions of hydrogen and nitrogen in the remaining gas difcovered by inflammation with atmofpheric air or oxygen in the detonating tube by the electric fpark.

The two following experiments on quantities of hydrogen, equal to thofe of the nitrous oxyd, refpired in the foregoing experiments, are the moft accurate of five.

Exp. 1. He refpired at 59°, 102 cubic inches of hydrogen, apparently pure; for rather lefs than half a minute, making feven quick refpirations. After the complete expiration, when the common temperature was reftored, the gas occupied a fpace equal to 103 cubic inches nearly. Thefe analyfed were found to confift of

Carbonic acid 4.0
Oxygen 3.7
Nitrogen 17.3
Hydrogen 78.0
_____
103.0
_____

Now, as in this experiment the gas was increafed in bulk only a cubic inch; fuppofing that after the complete expiration the gas in the lungs, bronchia, and fauces, was of nearly fimilar compofition with that in the air-holder, and that no hydrogen had been abforbed by the blood, it would follow that 24 cubic inches of hydrogen remained in the internal organs of refpiration, and confequently, by the rule of proportion, about 7.8 of the mixed refidual gas of the common air. And then the whole quantity of refidual gas of the lungs, fuppofing the temperature 59°, would have been 31.8 cubic inches; but as it's temperature was nearly that of the internal parts of the body, 98°, it muft have filled a greater fpace; calculating from the experiments of Guyton and Vernois (An. de Ch. t. i. p. 979) about 37.5 cubic inches.

From the increafe of volume, it would appear that a minute quantity of gas had been generated during the refpiration; and this was moft probably carbonic acid : for

there is no reafon to fuppofe the production of nitrogen. There is alfo reafon to fuppofe that a little of the refidual oxygen muft have been abforbed. Making allowances for thefe circumftances, it would follow that the 37.5 cubic inches of gas remaining in the lungs of the operator, after a complete expiration of atmofpheric air, animal heat 98°, equal to 31.3 cubic inches at 59°, were compofed of

Nitrogen 24.9
Carbonic acid 4.9
Oxygen 5.0
————
31.8

Exp. 2. He refpired for near a minute and a half in the mercurial air-holder at 61°, 182 cubic inches of hydrogen, making fix long infpirations. After the laft expiration, the gas filled a fpace nearly equal to 184 cubic inches, and analyfed was found to confift of

Carbonic acid 4.8
Oxygen 4.6
Nitrogen 21.0
Hydrogen 153.6
————
184.0

Now in this experiment, reafoning as before, 28.4 cubic inches of hydrogen muft have remained in the lungs, and likewife 5.5 of the atmofpheric refidual gas. Confequently, the whole refidual gas was nearly equal to 34 cubic inches at 61°, which at 98° would become about 40.4 cubic inches. And it would appear alfo, that the quantity of gas remaining in the lungs, after a complete voluntary refpiration, equalled at 98°, about 40 cubic inches, and at 61°, 34 nearly; that after common air had been breathed, the 34 cubic inches confifted of

Carbonic acid 4.1
Oxygen 5.5
Nitrogen 24.4

                        ————

                        34.0

It would have been poffible, according to the operator, to prove the truth of the poftulate on which the experiments were founded, by refpiring common air or oxygen after the complete expiration of the hydrogen, for the fame time as the hydrogen was refpired, and in equal quantities. For, if portions of hydrogen were found in the air-holder equal to thofe of the refidual gafes in the two experiments, it would prove that a *uniform* mixture of refidual gas, with the gas infpired, was produced by the refpiration. This mixture, however, appeared fo evident from analogous facts as to make the proofs unneceffary.

Indeed, as moft gafes, though of different fpecific gravities, when brought into contact with each other, affume fome fort of union, it is more than probable that gas infpired into the lungs, from being placed in contact with the refidual gas on fuch an extenfive furface, muft inftantly mingle with it. Hence, poffibly one deep infpiration and complete expiration of the whole of a quantity of hydrogen of the lungs after complete voluntary exhauftion, will be fufficient to determine the capacity and the nature of the refidual air.

That two infpirations are fufficient, appears probable from the following

Exp. 3. After a complete voluntary expiration of common air, he made two deep infpirations of 141 cubic inches of hydrogen. After the complete expiration, they filled a fpace equal to rather more than 142 cubic inches, and analyfed were found to confift of

Carbonic acid	3.1
Oxygen	4.5
Nitrogen	18.8
Hydrogen	115.6

142.0

Calculating from this experiment on the exhaufted capacity of the lungs, fuppofing uniform mixture, they would contain, after expiration of common air, about 30.7 cubic inches at 58°, equal to 36 at 98°, compofed of about

Nitrogen	20.9
Oxygen	5.8
Carbonic acid	4.0

30.7

It might be fuppofed, a *priori*, that in this experiment much lefs of the refidual oxygen of the lungs muft have been abforbed, than in experiments 1 and 2; yet there is no very marked difference in the portions evolved. That a tolerably accurate mixture took place, appears from the quantity of nitrogen. The fmaller quantity of carbonic acid is an evidence in favour of it's evolution from the venous blood.

It is reafonable to fuppofe that the preffure upon the refidual gas of the exhaufted lungs muft be nearly equal to that of the atmofphere; but as aqueous vapour is perpetually given out by the exhalents, and perhaps evolved from the moift coats of the pulmonary veffels, it is likely that the refidual gas is not only fully faturated with moifture at 98°, but likewife impregnated with uncombined vapour, and hence it's volume enlarged beyond the

increment of expansion of temperature. Considering all these circumstances, and calculating from the mean of the three experiments on the composition of the residual gas, Davy concludes—

1st. That the exhausted capacity of his lungs was equal to about 41 cubic inches.

2d. That the gas contained in the bronchial vessels and fauces, after a complete expiration of atmospheric air, was equal to about 32 cubic inches—it's temperature being reduced to 55°.

3d. That these 32 cubic inches were composed of about

                Nitrogen, ... 23.0
                Carbonic acid, ... 4.1
                Oxygen, ... 4.9
                                     ——
                              . 32.0
                                     ——

In many experiments made in the mercurial air-holder, on the capacity of the lungs under different circumstances, he found that he threw out of his lungs, by a full forced expiration, at temperature from 58° to 62°,

                                                Cubic Inches.
After a full voluntary inspiration, from 189 to 191
After a natural inspiration, from .... 78 to 79
After a natural expiration, from .... 67 to 68

So that, making the corrections for temperature, it would appear that his lungs in a state of voluntary inspiration contained about 254 cubic inches; in a state of natural inspiration about 135; in a state of natural expiration about 118; and in a state of forced expiration 41. But as the exhausted capacity, as well as impleted capacity, of the internal organs of respiration must be different in different individuals, according as the forms and size of their thorax, fauces, and bronchia are different, it would

be almost useless to endeavour to ascertain a standing ca-
pacity. It is, however, probable, that a ratio exists be-
tween the quantities of air inspired in the natural and
forced inspiration, those expired in the natural and forced
expiration, and the whole capacity of the lungs. If this
ratio were ascertained, a single experiment on the natural
inspiration and expiration of common air would enable
us to ascertain the quantity of residual gas in the lungs of
any individual after a complete forced expiration. The
operator is of opinion that the capacity of his own lungs
is below the medium—his chest being narrow, measuring
in circumference only twenty-nine inches, and his neck
rather long and slender.

Comments on the experiments on the respiration of nitrous oxyd.

Having thus ascertained the capacity of his lungs, and
the composition of the residual gas of expiration, it re-
mained to reason on the experiments on the respiration of
nitrous oxyd.

In experiment I, nearly 100 cubic inches of nitrous
oxyd (making the corrections on account of the common
air) were respired for half a minute. In this time they
were reduced to 62 cubic inches; which consisted of 3.2
carbonic acid, 29 nitrous oxyd, 4.1 oxygen, and 25.7
nitrogen.

But, as appears from the last section, there existed in
the lungs, before the inspiration of the nitrous oxyd,
about 32 cubic inches of gas, consisting of 23 nitrogen,
4.1 carbonic acid, and 4.9 oxygen—temperature being
reduced to 59°. This gas must have been perfectly min-
gled with the nitrous oxyd during the experiment; and,
consequently, the residual gas in the lungs, after the ex-
periment, was of the same composition as that in the
air-holder.

Supposing it, as before, to be about 32 cubic inches,
from the rule of proportion they will be composed of

Nitrous oxyd, ... 14.7
Nitrogen, ... 13.3
Carbonic acid, ... 1.9
Oxygen, ... 2.1

32.0

And the whole quantity of gas in the lungs and the air-holder, fuppofing the temperature 59°, will equal 94 cubic inches; which are compofed of

Nitrous oxyd, ... 43.7
Nitrogen, ... 39.0
Carbonic acid, ... 5.2
Oxygen, ... 6.1

94.0

But, before the experiment, the gas in the lungs and air-holder equalled 134 cubic inches; and thefe, reckoning for the common air, were compofed of

Nitrous oxyd 100.0
Nitrogen, ... 24.3
Carbonic acid, ... 4.1
Oxygen, ... 5.6

134.0

Hence it appears, that 56.3 cubic inches of nitrous oxyd were abforbed in this experiment, and 13.7 of nitrogen produced, either by evolution from the blood, or decompofition of the nitrous oxyd. The quantities of carbonic acid and oxygen approach fo near to thofe exifting after the refpiration of hydrogen, that there is every reafon to believe that no portion of them was produced in confequence of the abforption or decompofition of the nitrous oxyd.

In Experiment II, calculating in the fame manner, before the firft infpiration a quantity of gas, equal to 216.5 cubic inches at 47°, exifted in the lungs and air-holder; and thefe 216.5 were compofed of

<div style="text-align:center">

Nitrous oxyd, ...	182.0
Nitrogen, ...	24.9
Carbonic acid, ...	4.1
Oxygen, ...	5.5
	216.5

</div>

After the complete expiration, 160 cubic inches remained in the lungs and air-holder; which were compofed of

<div style="text-align:center">

Nitrous oxyd, ...	110.6
Nitrogen, ...	36.3
Carbonic acid, ...	6.8
Oxygen, ...	6.3
	160.0

</div>

Hence it appears that 71.4 cubic inches of nitrous oxyd were abforbed in this experiment, and about 12 of nitrogen produced. The quantity of carbonic acid and oxygen is rather greater than that which exifted in the experiments on hydrogen.

Nitrogen produced during re-fpiration of nitrous oxyd.

From thefe eftimations he learned that a fmall quantity of nitrogen was produced during the abforption of nitrous oxyd in refpiration. It remained to determine whether this nitrogen owed it's production to evolution from the blood, or to the decompofition of a portion of the nitrous oxyd.

Analogical evidences were not in favour of the hypothefis of decompofition. It was difficult to fuppofe that a body requiring the temperature of ignition for it's decompofition by the moft inflammable bodies, fhould be partially abforbed and partially decompounded at 98° by a fluid apparently poffeffed of uniform attractions. It was more eafy to believe that, from the immenfe quantity

of nitrogen taken into the blood in nitrous oxyd, the syf-
tem soon became overcharged with this principle; which
not being wholly expended in new combinations during
living action, was liberated in the aeriform state by the
exhalants, or through the moist coats of the veins. If
the last rationale were true, it would follow that the quan-
tity of nitrogen produced in respiration ought to be in-
creased in proportion as a greater quantity of nitrous oxyd
entered into combination with the blood.

To ascertain whether this was the case, he made, after
full voluntary exhaustion of his lungs, one full voluntary
inspiration and expiration of 108 cubic inches of nitrous
oxyd. After this it filled a space nearly equal to 99 cubic
inches; the quantities of carbonic acid and oxygen in
these were not determined; but by the test of absorption
by water, they appeared to contain only 18 nitrogen,
which is very little more than should have been given
from the residual gas of the lungs. In a second experi-
ment he made two inspirations of 108 cubic inches of
nitrous oxyd nearly pure : the diminution was to 95. On
analysing these 95, he found, to his great surprise, they
contained only 17 nitrogen. Hence he suspected some
source of errour in the process.

He now introduced into a strong new silk bag, the sides
being in perfect contact, eight quarts of nitrous oxyd : it
was mingled, from the mode of introduction, with a
little common air, but not sufficient to disturb the results.
He then adapted a cork cemented to a long curved tube
to his right nostril; the tube communicated with the water
apparatus ; and the left nostril being accurately closed,
and the mouth-piece of the silk bag lightly adapted to the
lips, he made a full expiration of the common air of his
lungs, inspired nitrous oxyd from the bag, and, by care-
fully closing the mouth-piece with his tongue, expired it
through the curved tube into the water apparatus. In

this way he made nine refpirations of nitrous oxyd. The expired gas of the firft refpiration was not preferved; but part of the gas of the 2d, 3d, 5th, 7th, and 9th, were caught in feparate graduated cylinders. The 2d, analyfed by abforption, confifted of about 29 abforbable gas, which muft have been chiefly nitrous oxyd; and 17 unabforbable gas, which muft have been chiefly nitrogen; and the 3d of 22 abforbable gas and eight unabforbable. The fifth was compofed of 27 to 6; the 7th of 23 to 7; and the 9th of 26 to 11.

Though the refults of thefe experiments were not fo conclufive as could be wifhed; yet, comparing them with thofe of the experiments on the changes effected in nitrous oxyd by refpiration, it feemed reafonable to conclude that the production of nitrogen was increafed in proportion as the blood became more fully impregnated with nitrous oxyd.

From this conclufion, compared with the phenomena noticed on the abforption of nitrous oxyd by venous blood, and on the changes effected on the organifation of warm-blooded animals, by the refpiration of nitrous oxyd, he is induced to believe that the production of nitrogen, during the refpiration of nitrous oxyd, is not owing to the decompofition of part of the nitrous oxyd in the aëriform ftate *immediately* by the attraction of the red particles of

Production of nitrogen from the new arrangement in the principles of the impregnated blood.

venous blood for it's oxygen; but that it is rather owing to a new arrangement produced in the principles of the impregnated blood during circulation; from which, becoming fuperfaturated with nitrogen, it gives it out through the moift coats of the veffels.

For if any portion of nitrous oxyd were decompofed immediately by the red particles of the blood, the quantity of nitrogen produced ought to be greater during the firft infpirations, before thefe particles became fully combined with condenfed oxygen. If, on the contrary, the

whole of the nitrogen and oxygen of the nitrous oxyd were both combined with the blood and carried through the pulmonary veins and left chamber of the heart to the arteries, then, fuppofing the oxygen chiefly expended in living action, whilft the nitrogen was only partially confumed in new combinations, it would follow that the venous blood of animals made to breathe nitrous oxyd, hyperfaturated with nitrogen, muft be different from common venous blood; and there is reafon to believe this from the phenomena, on the changes effected in the organifation of warm-blooded animals by the refpiration of nitrous oxyd.

Befides nitrogen, carbonic acid and water have been noticed to be the products of the refpiration of nitrous oxyd. *Of the other products, carbonic acid and water.*

As nearly equal quantities of carbonic acid are produced, whether hydrogen or nitrous oxyd is refpired, provided the procefs is carried on for the fame time, there is every reafon to believe that no part of the carbonic acid produced is generated from the immediate decompofition of nitrous oxyd by carbon exifting in the blood : hence it muft be either evolved from the venous blood, or formed by the flow combination of the oxygen of the refidual air of refpiration with the charcoal of the blood.

But if it was produced from the decompofition of refidual atmofpheric air, it would follow that it's volume muft be much lefs than that of the oxygen of the refidual air which had difappeared ; for fome of this oxygen muft have been *abforbed* by the blood, and during the converfion of oxygen into carbonic acid by charcoal a flight diminution of volume is produced.

In the experiments when nitrous oxyd and hydrogen were refpired for half a minute, the medium quantity of carbonic acid produced was 5.6 cubic inches.

Suppofe the quantity of carbonic acid produced is in

the ratio of the oxygen diminished, and there is every reason to believe that, in the expiration of atmospheric air, the expired air and the residual air are nearly of the same composition. Hence no more carbonic acid can remain in the lungs, or be produced from the residual gas, after the complete expiration of common air, than that which can be generated from a volume of atmospheric air equal to the residual gas of the lungs. This residual gas, after complete expiration, equals at 55°, 32 cubic inches, and 32 cubic inches of common air contain 8.6 cubic inches of oxygen. But in the experiments on the respiration of hydrogen, not only 5.6 cubic inches of carbonic acid were produced, but more than four of residual oxygen remained unabsorbed.

The carbonic acid evolved through the coats of the vessels.

Hence it appears impossible that all the carbonic acid could have been produced by the combination of charcoal in the venous blood with residual atmospheric oxygen; there is therefore every reason to believe, that it is wholly or partially liberated from the venous blood through the moist coats of the vessels. The water carried out of the lungs in solution, by the expired gas of nitrous oxyd, could neither have been wholly nor partially formed by the decomposition of nitrous oxyd. The coats of the vessels in the lungs, and indeed in the whole internal surface of the body, are always covered with moisture ; and the solution of part of this moisture by the inspired heated gas, and it's deposition by the expired gas, are, according to Davy, sufficient causes for the appearance of the phenomenon. There are no reasons for supposing that any of the residual atmospheric oxygen is immediately combined with fixed or nascent hydrogen, or hydrocarbonat, in the venous blood, at 98°, by slow combustion, and consequently none for supposing that water is immediately formed in respiration. The evolution of water from the vessels in the lungs is almost certain from nu-

The water evolved from the

merous analogies. He found that nitrous oxyd can be refpired without danger by man for a much longer time than that required for the death of the fmaller quadrupeds in it. He has breathed it two or three times in a confiderable ftate of purity for four minutes and a quarter, and four minutes and a half, and fome difeafed individuals for five minutes. Three quarts, *i. e.* about one hundred and feventy-four cubic inches, are confumed fo as to be unfit for refpiration by a healthy individual with lungs of moderate capacity in about one minute and a quarter; fix quarts, or 348 cubic inches, laft generally for two minutes and half or two minutes and three quarters; eight quarts, or 464 cubic inches, for more than three minutes and half; and 12 quarts, or 696 cubic inches, for nearly five. He is inclined to believe that nitrous oxyd is abforbed more rapidly after heavy meals, or during ftimulation from wine or fpirits, than at other times; and as it's abforption appears to depend on a fimple folution in the venous blood, probably diminution of temperature will increafe it's capability of being abforbed. The range of the confumption of different individuals does not extend to more than a pint, or 30 cubic inches, at the maximum dofe; hence the medium of confumption is not far from two cubic inches, or about a grain every fecond, or 120 cubic inches, or 60 grains, in a minute. When nitrous oxyd is breathed in tight filk bags, towards the end of the experiment, as the internal furface becomes moift, a certain quantity of common air penetrates through; but it is too fmall to deftroy any of the effects of the nitrous oxyd.

Having thus afcertained the abforption of nitrous oxyd in refpiration, and the evolution of nitrogen and carbonic acid from the lungs, during it's abforption, he was anxious to compare the changes effected in this gas, with thofe produced in nitrous oxyd and oxygen; confidering

atmofpheric air as a compound, in which principles iden-tical with thofe in nitrous oxyd exifted, though in dif-ferent quantities and loofer combination.

The compofition of the atmofpheric air before infpira-tion, and after expiration, was afcertained in the follow-ing manner: 40 meafures of it were agitated over mer-cury in folution of cauftic potafh, and here it remained two or three hours in contact. The diminution was noted, and the gas abforbed judged to be carbonic acid. Twenty meafures of the gas, freed from carbonic acid, were mingled with 30 of nitrous gas, in a tube of five inches diameter; they were *not agitated*, but fuffered to reft an hour or an hour and half, when the volume occu-pied by them was noticed; and 50—m the volume oc-cupied, divided by three, confidered as the oxygen x, and 20—x confidered as the nitrogen. When they are *agita-ted* a greater proportion of nitrous gas is abforbed and condenfed in the nitric acid by the water; and to find the oxygen $x = \frac{50-m}{3.4}$ or $\frac{50-m}{3.5}$

Exp. 1. To afcertain the changes effected in atmo-fpheric air by fingle infpirations, he made after a com-plete voluntary exhauftion of his lungs, at temperature 61°, one infpiration and expiration of 141 cubic inches of this air. After expiration they filled a fpace equal to 139 cubic inches. Thefe analyfed were found to confift of

Nitrogen 101
Oxygen 32
Carbonic acid .. 6

The 141 cubic inches before refpiration were com-pofed of 103 nitrogen, 1 carbonic acid, and 37 oxygen. The time taken to perform the infpiration and full expi-ration was a quarter of a minute. He repeated this ex-periment feven or eight times, and the quantity of oxygen abforbed was generally from five to fix cubic inches;

the carbonic acid formed from five to 5.5, and the quantity of nitrogen apparently diminished from one to three cubic inches.

Exp. 2. After a voluntary expiration of common air, he made one inspiration and full expiration of 100 cubic inches of atmospheric air. It was diminished nearly to 98¼ or 99 cubic inches, and, analysed, was found to consist of

Nitrogen 71.7
Oxygen 22.5
Carbonic acid 4.5

This was repeated four or five times with little difference of result, and there always seemed to be a small diminution of nitrogen. He found he took into his lungs at every natural inspiration 13 cubic inches of air, and threw out at every expiration rather less, or about 12¾ cubic inches.

The mean composition of the 13 cubic inches of air inspired was

Nitrogen .... 9.5 cubic inches
Oxygen 3.4
Carbonic acid ... 0.1

That of the 12.7 of air expired

Nitrogen .... 9.3 cubic inches
Oxygen 2.2
Carbonic acid 1.2

These results he gained from more than 20 experiments, which show their accuracy. He made about 26 or 27 natural inspirations a minute. So that, calculating from the above estimations, it follows, that 31.6 cubic inches of oxygen were consumed, and 5.2 cubic inches of nitrogen-lost in respiration every minute, whilst 26.6 cubic inches of carbonic acid were produced.

To collect the products of a great number of natural expirations, so as to ascertain whether their composition

corresponded with the above accounts, he fastened his lips tight on the mouthpiece of the exhausted airholder, and, suffering his nostrils to remain open, inspired naturally through them, throwing the expired air through his mouth into the airholder.

In many experiments, he found that in about half a minute he made in this way 14 or 15 expirations. The mean quantity of air collected was 171 cubic inches, and consisted of

> Nitrogen .... 128 cubic inches
> Oxygen. 29
> Carbonic acid 14

On comparing these results with the former ones, the mean quantities of air respired in equal times are rather less; but the proportions of carbonic acid, nitrogen, and oxygen, in the respired air, nearly identical.

To ascertain the changes effected in a given quantity of atmospheric air by continued respirations, he breathed, after a complete expiration, at temperature 63°, 161 cubic inches of air for near a minute, making 19 deep inspirations. After the complete expiration, the gas filled a space nearly equal to 152 cubic inches, so that nine cubic inches of gas had disappeared.

The 152 cubic inches, analysed, were found to consist of

> Nitrogen .... 111.6 cubic inches
> Oxygen, ... 23.
> Carbonic acid 17.4

The 161 cubic inches before inspiration were composed of

> Nitrogen .... 117.0 cubic inches
> Oxygen 42.4
> Carbonic acid 1.6

But the residual gas in the lungs, before the experiment, was of different composition from that remaining in the lungs after the experiment. It appears, therefore, after

making proper corrections, that about 5.1 of nitrogen were abforbed in refpiration, 23.9 of oxygen confumed, and 12 of carbonic acid produced. This e periment was repeated three times with fimilar refults, and the refidual gas of fimilar compofition. So that, fuppofing the exiftence of no fource of error in the experiments, from which the quantity and compofition of the refidual gas of the lungs were eftimated, the abforption of nitrogen as Prieftley had fufpected, by venous blood, appears demonftrated. To compare the changes effected in atmofpheric air by refpiration of the fmaller quadrupeds with the above, he introduced into a 20-cubic-inch jar, filled with mercury in the mercurial trough, 15 cubic inches of atmofpheric air, deprived of it's carbonic acid by long expofure to folution of potafh. Temperature being 64°, a healthy fmall moufe was quickly paffed under the mercury into the jar. He continued nearly 49 minutes without apparently fuffering, at 20 minutes he lay on his fide, and in 55 minutes was apparently dying, but expofed to the warmth of a fire recovered. The gas in the jar filled a fpace nearly equal to 14 cubic inches ; fo that a diminution of a cubic inch had taken place. Thefe 14 cubic inches, analyfed, confifted of

> Carbonic acid .... 2.0 cubic inches
> Oxygen 1.4
> Nitrogen 10.6

The 15 cubic inches before the experiment confifted of

> Oxygen .... 4 cubic inches
> Nitrogen 11

Hence 2.6 cubic inches of oxygen had been confumed, two cubic inches of carbonic acid produced, and about 0.4 of nitrogen loft. The relation, therefore, between the quantities of oxygen confumed, and carbonic acid produced, are nearly the fame as thofe in the former experiments; but the quantity of nitrogen loft is much fmaller.

The gafes before and after refpiration were analyfed in
thefe experiments as in the laft, except that three of ni-
trous gas were always employed to one of oxygen.

Exp. 1. At temperature 53°, after a full forced expira-
tion, he refpired in the mercurial airholder, for half a mi-
nute, 102 cubic inches of oxygen, making feven long and
deep infpirations. After the complete expiration, the
gafes filled a fpace equal to 93 cubic inches : thefe 93,
analyfed, confifted of

> Carbonic acid .... 5.9 cubic inches
>
> Nitrogen 33.8
>
> Oxygen 53.3

The 102 cubic inches before the experiment were
compofed of

> Oxygen .... 78 cubic inches
>
> Nitrogen 24

The refidual gas in the lungs, before the experiment,
was 32 cubic inches, and compofed of 23 nitrogen, 4.1
carbonic acid, and 4.9 oxygen. The refidual gas, after
expiration, of 18.2 oxygen, two carbonic acid, and 11.8
nitrogen.

Hence the whole of the gas in the lungs and airholder
before infpiration was 134 cubic inches, compofed of

> Oxygen .... 82.9 cubic inches
>
> Nitrogen 47.0
>
> Carbonic acid ... 4.1

and after refpiration, 125 cubic inches, confifting of

> Oxygen .... 71.5 cubic inches
>
> Nitrogen 45.6
>
> Carbonic acid ... 7.9

fo that, comparing the quantities, it appears that 11.4 of
oxygen, and 1.4 of nitrogen, were confumed in this ex-
periment, and 3 8 of carbonic acid produced. He was
furprifed at the fmall quantity of oxygen confumed, being
lefs than that during the refpiration of atmofpheric air

for half a minute: the portion of carbonic acid evolved was smaller.

Exp. 2. He respired at the same temperature, after a full expiration, 162 cubic inches of gas, composed of 133 oxygen, and 29 nitrogen, for two minutes. After the experiment they were equal to 123 cubic inches. On analysis it appeared, that 57 cubic inches of oxygen, and two of nitrogen, had been absorbed, whilst 21 cubic inches of carbonic acid had been formed. It appears, therefore, from the estimations in the last section, that 63 cubic inches of oxygen are consumed, and about 52 cubic inches of carbonic acid produced, every two minutes, during the natural respiration of common air. So that six cubic inches less of oxygen are absorbed, and 30 cubic inches less of carbonic acid produced, every minute, when oxygen nearly pure is respired than when atmospheric air is respired.

Comparative consumption of atmospheric air and oxygen.

To ascertain the comparative consumption of atmospheric air and oxygen, by the smaller quadrupeds, he procured two healthy mice.

Exp. 3. One was introduced into a jar, containing $10\frac{1}{2}$ cubic inches of oxygen, and three cubic inches of nitrogen, and made to rest on a bit of cheese. The other was introduced into a jar containing $15\frac{1}{2}$ cubic inches of atmospheric air. In the first it suffered in half an hour, and was dying in one hour. The jars were often agitated, that the gases might be well mingled. The mouse in the atmospheric air was feeble in 40 minutes, and in 50 unable to stand.

The gas in the oxygen jar filled a space equal to 12.7 cubic inches, and, analysed, consisted of 1.7 carbonic acid, 2.6 nitrogen, and 8.4 of oxygen. So that 2.1 cubic inches of oxygen had been consumed, and 0.4 of nitrogen, and 1.7 of carbonic acid produced.

The gas in the atmospheric jar was diminished nearly

to 14.4, and consisted of 2.1 carbonic acid, 1.4 oxygen, and 10.9 nitrogen. So that 2.7 of oxygen, and five of nitrogen had been consumed, and 2.1 of carbonic acid produced.

It appears therefore that the mouse in atmospheric air consumed nearly one third more oxygen, and produced nearly a quarter more carbonic acid in 55 minutes than the other in an hour and a quarter in oxygen.

On the changes effected in the blood by atmospheric air and oxygen.

From the experiments of Cigna and Priestley, the coagulum of the venous blood becomes florid at it's surface when exposed to the atmosphere, though covered and defended from the immediate contact of the air by a very dark stratum of serum. Hence serum is capable of dissolving either the whole compound atmospheric air, or it's oxygen. Supposing it dissolves the whole, it follows, that the colouring of the coagulum of blood under serum depended on the decomposition of the atmospheric air condensed in the serum; it's oxygen combining with the red particles and the nitrogen, either remaining dissolved in the fluid, or being liberated through it into the atmosphere; for the circulating blood consists of red particles, floating in and diffused through serum and coagulable lymph. In natural respiration, the red particles are rendered of a brighter tinge during the passage of the blood through the pulmonary veins: and, as before seen, during respiration, atmospheric air is decomposed, all the oxygen of it consumed, *apparently* a small proportion of the nitrogen lost, and a considerable quantity of carbonic acid produced.

Most probably, the whole compound atmospheric air, passing through the moist coats of the vessels, is first dissolved by the serum of the venous blood, and in it's condensed state decomposed by the affinity of the red particles for it's oxygen, the greater part of the nitrogen being liberated unaltered, but a minute portion of it possibly re-

2

maining condenfed in the ferum and coagulable lymph, and paffing with them into the left chamber of the heart.

From the experiments on the refpiration of nitrous oxyd and hydrogen, it appears that a certain portion of the carbonic acid produced is evolved from the venous blood; but, as a much greater quantity is generated during the refpiration of common air and oxygen than during that of hydrogen in equal times, it is not impoffible but that fome portion of it may be formed by the combination of charcoal in the red particles with the oxygen diffolved in the ferum.

Suppofing that no part of the water evolved in folution by the expired gas of common air is formed immediately in refpiration, it will follow that a very confiderable quantity of oxygen muft be conftantly *combined* with the red particles, even allowing the confumption of a certain portion of it to form carbonic acid; for the carbonic acid evolved rarely amounts to more than three-fourths of the volume of the oxygen confumed. Perhaps the ferum is capable of diffolving a larger quantity of atmofpheric air than of pure oxygen.

It therefore appears that nitrous oxyd, when refpired by animals, produces peculiar changes in their blood and in their organs, firft connected with increafed living action, but terminating in death; that it is rapidly abforbed by the circulating venous blood, and of courfe it's condenfed oxygen and nitrogen diftributed in the blood over the whole of the fyftem.

Obfervations on the refpiration of nitrous oxyd.

He could breathe nine quarts of nitrous oxyd for three minutes, and twelve for rather more than four, but could never breathe it in any quantity fo large as five. When it's operation was carried to the higheft extent, the pleafurable thrilling about it's height about the middle of the experiment gradually diminifhed, the fenfe of preffure on

the mufcles was loft, impreffions ceafed to be perceived, voluntary power deftroyed, and the mouthpiece generally dropped from his unclofed lips.

He made fome experiments to afcertain the analogy that exifted between the fenfible effects of the different gafes, which are fooner or later fatal to life when refpired, and thofe of nitrous oxyd.

Hydrogen.   Pure hydrogen had been often refpired by different phi-lofophers, particularly by Scheele, Fontana, and Rofier. Davy refpired four quarts of it, nearly pure, produced from zinc and muriatic acid, for near a minute; his lungs being previoufly exhaufted, and his noftrils care-fully clofed. The firft fix or feven infpirations produced no fenfations whatever; in half a minute his cheft was oppreffed, which gradually increafed until the pain of fuffocation obliged him to leave off. He felt no giddi-nefs, his pulfe was feebler and quicker, and his cheeks at laft became purple. When the hydrogen was procured from iron and diluted vitriolic acid, he was unable to re-fpire three-fourths of a minute; giddinefs and debility were produced, the pulfe feeble, and the fuffocation greater than before.

Nitrogen.   He breathed three quarts of nitrogen, mingled with a very fmall portion of carbonic acid, for near a minute. It produced no alteration for twenty feconds; then the fenfe of fuffocation gradually came on, and increafed rapidly the laft quarter of the minute, fo as to compel him to defift. The pulfe was feebler and quicker. The head not affected.

Hydro-car-   Watt's obfervations on the refpiration of diluted hydro-
bonat.   carbonat by men, and Dr. Beddoes' experiments on ani-mals by pure hydro-carbonat, proved it's effects to be highly deleterious. Davy breathed for near a minute three quarts of it mingled with nearly two quarts of at-mofpheric air, which had never been breathed fo little

diluted before. It produced a flight giddinefs and pain in the head, and a momentary lofs of voluntary power. He then refolved to breathe pure hydro-carbonat: for this purpofe, he introduced into a filk bag four quarts of gas, nearly pure, produced from the decompofition of water by charcoal an hour before, and which had a ftrong and difagreeable fmell. After a forced exhauftion of the lungs, and the nofe being accurately clofed, he made three infpirations and expirations. The firft produced a fort of numbnefs and lofs of feeling in the cheft, and about the pectoral mufcles. After the fecond infpiration he loft all power of perceiving external things, and had no diftinct fenfation, except a terrible oppreffion on the cheft. During the third expiration this feeling difappeared, and he feemed finking into annihilation, and had juft power enough to drop the mouth-piece from his unclofed lips. He was very ill and feeble after. He thinks it proves that hydro-carbonat acts as a fedative; *i. e.* it produces diminution of vital action and debility, without previoufly exciting. He thinks four or five infpirations inftead of three would have deftroyed life immediately, without producing any painful fenfation.

He attempted to refpire carbonic acid, not being then Carbonic acquainted with the experiments of Rofier: he intro- acid. duced into a filk bag four quarts of well wafhed carbonic acid, produced from carbonat of ammonia by heat (which is in a high ftate of purity, and readily effected), and after a complete voluntary exhauftion of his lungs attempted to infpire it. It produced a fenfe of burning at the top of the uvula. It was in vain to make voluntary efforts to inhale it; at the moment the epiglottis was raifed a little, a painful ftimulation was induced, fo as to clofe it fpafmodically on the glottis. Thus, after repeated trials, he was prevented from taking a fingle particle of carbonic acid into the lungs.

He tried to breathe a mixture of two quarts of common air and three of carbonic acid, without fuccefs, it being nonrefpirable. He found a mixture of three quarts of carbonic acid with feven of common air to be refpirable, and breathed it for near a minute. It produced a flight giddinefs and inclination to fleep. They however rapidly difappeared after ceafing to refpire it. Carbonic acid poffeffes no action on arterial blood : hence perhaps it's flight effects when breathed, mixed with large quantities of common air. It's effects are very marked upon venous blood.

Oxygen. The oxygen was procured from manganefe by heat. In refpiring eight or ten quarts, for the firft two or three minutes, he perceived no effect. Towards the end his refpiration became oppreffed, and he felt a fenfation as if he wanted frefh air, though but little of the oxygen had been confumed. In one experiment, when he breathed from and into a bag containing twenty quarts of oxygen for near fix minutes, his pulfe was not altered in velocity, but rather harder than before. He perceived no effects but thofe of oppreffion on the cheft. Watt had fufpected that the effects attributed to oxygen produced from manganefe by heat, in fome meafure depended upon nitrous acid, fufpended in the gas formed during ignition by the union of the oxygen of the manganefe, with nitrogen likewife condenfed in it; and in the courfe of his experiments on nitrous acid, Davy feveral times experienced a fevere oppreffion on the cheft and difficulty of refpiration, not unanalogous to that produced by oxygen, but more violent ; which feems to confirm Watt's fufpicion.

Nitrous gas. Being refolved to endeavour to breathe the nitrous gas, he introduced 114 cubic inches of it into a large mercurial airholder : two fmall filk bags of the capacity of feven quarts were filled with nitrous oxyd. After a forced exhauftion of his lungs, his nofe accurately clofed, he

made three infpirations and expirations of nitrous oxyd in one of the bags, to free his lungs as much as poffible from atmofpheric oxygen ; then after a full expiration of the nitrous oxyd, he transferred his mouth from the mouthpiece of the bag to that of the airholder, and turning the ftop-cock, attempted to infpire the nitrous gas. In paffing through his mouth and fauces it tafted aftringent and highly difagreeable, caufed a fenfe of burning in the throat, and a fpafm of the epiglottis fo painful as to oblige him immediately to defift. After moving his lips from the mouthpiece which he opened to infpire common air, aëriform nitrous acid was inftantly formed in his mouth, which burnt the tongue and palate, and inflamed the mucous membrane. He never intends again to attempt fo rafh an experiment.

He frequently refpired nitrous oxyd mingled with different proportions of common air or oxygen, and the effects produced by the diluted gas were much lefs violent than thofe produced by pure nitrous oxyd. They were generally pleafant, the thrilling was not often perceived, but a fenfe of exhilaration was almoft conftant. *Moft extenfive action of nitrous oxyd produces no debility.*

Immediately after a journey of 126 miles, being much exhaufted from having had no fleep the preceding night, he refpired feven quarts of nitrous oxyd for near three minutes. It produced the ufual pleafurable effects. He continued exhilarated for fome minutes afterwards, and in half an hour found himfelf neither more or lefs exhaufted than before the experiment : he had a great propenfity to fleep. He repeated the experiment four or five times the following week with the fame effect. He had experienced no decifive exhauftion after the excitement, although he was ftill far from being fatisfied it was unanalogous to ftimulants in general.

It occurred to him, that, fuppofing nitrous oxyd to be a ftimulant of the common clafs, the debility produced in confequence of exceffive ftimulation by a known agent,

ought to be *increased* after excitement from nitrous
oxyd.

He therefore drank a bottle of wine in large draughts
in lefs than eight minutes (being accuftomed to drink
only water), which intoxicated him. Having remained
in a ftate of infenfibility for two hours and a half, he
awakened with head-ach and painful naufea. His bodily
and mental debility was exceffive, and his pulfe feeble
and quick. He then refpired twelve quarts of oxygen for
nearly four minutes; and he fuppofed he was fomewhat
exhilarated. The head-ach and debility ftill continuing
with violence, he refpired feven quarts of pure nitrous
oxyd for two minutes and a half. He was unconfcious
of head-ach after the third infpiration, and was exceed-
ingly exhilarated. The next morning he was well. This
proves that debility from intoxication was not increafed
by excitement from nitrous oxyd.

To afcertain with certainty whether the moft extenfive
action of nitrous oxyd compatible with life was capable
of producing debility, he refolved to breathe the gas for
fuch a time and in fuch quantities as to produce excite-
ment equal in duration, and fuperior in intenfity, to that
occafioned by high intoxication from opium or alcohol.
To habituate himfelf to the excitement, and carry it on
gradually, he was enclofed in an air-tight breathing box
of the capacity of $9\frac{1}{2}$ feet. Taking a fituation in which
he could, by means of a curved thermometer inferted
under the arm, and a ftop watch, afcertain his pulfe and
animal heat, twenty parts of nitrous oxyd were thrown
into the box; the fmell and tafte were immediately evi-
dent. In four minutes he felt a flight glow in the cheeks
and a diffufed warmth over the cheft, though the
temperature of the box was not quite $50°$; his pulfe
was 104 and hard, the animal heat $98°$. In ten mi-
nutes the animal heat was near $99°$; in a quarter
of an hour $99.5°$, and the pulfe 102, and fuller than

before. Twenty quarts more were now thrown into the
box, and well mingled by agitation. In twenty five
minutes the animal heat was 100°, pulfe 124. In thirty
minutes twenty quarts more were introduced : his fenfa-
tions were exhilaration, a generally diffufed warmth, and
a difpofition to mufcular motion and merriment. In three
quarters of an hour the pulfe was 104, animal heat not
99.5°, the temperature of the chamber was 64, the plea-
furable feelings increafed, the pulfe fuller and lower ; and
in about one hour it was 88, and the animal heat 99°.
Twenty quarts more were admitted. He had now a
great difpofition to laugh, luminous points paffed before
the eyes, his hearing more acute, and a pleafant light-
nefs and power of exertion were felt in his mufcles. The
fymptoms then became ftationary, refpiration rather op-
preffed, and from the great defire of action reft was pain-
ful. He now came out of the box, having been in pre-
cifely one hour and a quarter.

He immediately began to refpire twenty quarts of pure
nitrous oxyd ; a thrilling extending from the cheft to the
extremities was almoft immediately produced ; his plea-
furable fenfations increafed, he loft all connexion with
external things, and he exifted in a world of newly con-
nected and newly modified ideas. When awakened from
this femidelicious trance by the bàg being taken from his
mouth, indignation and pride were his firft feelings at
fight of thofe around him ; his emotions were enthufiaftic
and fublime. Three minutes and a half had only elapfed
during the experiment, but, from the relative vividnefs of
the recollected ideas, it appeared much longer to him.
Not more than half of the nitrous oxyd was confumed.
After a minute, before the thrilling of the extremities had
difappeared, he breathed the remainder. Similar fenfa-
tions were again produced ; he was thrown into the plea-
furable trance, which continued longer than before. He

ate his dinner with great appetite, found himself unufually
cheerful and active at night, enjoyed profound repofe in
bed, and awoke in the morning with confcioufnefs of
pleafurable exiftence, which continued more or lefs
through the day.

He has fince often breathed the nitrous oxyd, and his
fufceptibility to it's power is rather increafed than dimi-
nifhed. He finds fix quarts a full dofe, but is rarely
able to refpire it in any quantity for more than two mi-
nutes and a half. The mode of it's operation however is
fomewhat altered, and is very different at different times.
He is fcarcely ever excited into violent mufcular action ;
the emotions are generally much lefs intenfe and fublime
than in the former experiments, and not often connected
with thrilling in the extremities. When troubled with
indigeftion, he was two or three times unpleafantly af-
fected. Cardialgia, eructations, and unpleafant fulnefs
of the head were produced. He has often felt great plea-
fure when breathing it alone, in darknefs and filence, oc-
cupied only by ideal exiftence. In two or three inftances,
when breathed amidft noife, the fenfe of hearing has been
painfully affected even by moderate intenfity of found.
The light of the fun has fometimes been difagreeably
dazzling. Whenever breathed after excitement from
moral or phyfical caufes, the delight has been often in-
tenfe and fublime.

Conclufion.   From the facts already laid down, it appears that the
immediate effects of nitrous oxyd upon the living fyftem
are analogous to thofe of diffufible ftimuli : both increafe
the force of circulation, produce pleafurable feeling, alter
the condition of the organs of fenfation, and in their
moft extenfive action deftroy life. In the mode of ope-
ration of nitrous oxyd and diffufible ftimuli, confiderable
differences, however, exift. Diffufible ftimuli act im-
mediately on the mufcular and nervous fibre : nitrous

oxyd acts upon them only by producing peculiar changes in the composition of the blood. Diffusible stimuli affect that part of the system most powerfully to which they are applied, and act on the whole only by sympathy with that part: nitrous oxyd, in combination with the blood, is universal in it's application and action.

As life depends immediately on certain changes effected in the blood in respiration, and ultimately on the supply of certain nutritive matter by the lymphatics, it is reasonable to conclude, that during the action of stimulating substances, from the increased force of circulation, not only more oxygen, and perhaps nitrogen, must be combined with the blood in respiration, but also more fluid nutritive matter supplied to it in circulation.

By this oxygen and nutritive matter excitability may be kept up; and exhaustion, consequent to excitement, only produced, from a deficiency of some of the nutritive principles, supplied by absorption. Then nitrous oxyd is breathed; nitrogen (which in fluid compounds is carried into the blood by the absorbents) is supplied in respiration; a greater quantity of oxygen is combined with the blood than in common respiration, whilst less carbonic acid and probably less water are evolved. Hence probably a smaller quantity of nutritive matter is required from the absorbents during the excitement from nitrous oxyd, than during the operation of stimulants; and, in consequence, exhaustion from the expenditure of nutritive matter more seldom occasioned.

He has lately endeavoured to ascertain the quantities of nitrogen produced, when nitrous oxyd is respired for a considerable time. In one experiment, when he breathed about four quarts of gas in a glass bell over impregnated water for near a minute, it was diminished to about two quarts, and the residuum extinguished flame.

Now his experiments prove, that, when nitrous oxyd
is decompofed by combuftible bodies, the quantity of ni-
trogen evolved is rather greater in volume than the pre-
exifting nitrous oxyd. Hence much of the nitrogen taken
into the fyftem during the refpiration of nitrous oxyd
muft be either carried into new combinations, or given
out by the capillary veffels through the fkin. The va-
rious effects of nitrous oxyd upon different individuals,
and upon the fame individual at different times, prove
that it's powers are capable of being modified, both by
the peculiar condition of the organs, and by the ftate of
general feeling. It is probable that pleafurable feeling is
uniformly connected with a moderate increafe of nervous
action; and this increafe, when carried to certain limits,
produces mixed emotion or fublime pleafure, and beyond
occafions abfolute pain. From comparing facts, it is
likely that individuals poffeffed of high health and little
fenfibility will generally be lefs pleafurably affected by
nitrous oxyd, than fuch as have more fenfibility, in whom
the emotions will fometimes fo far enter the limits of pain
as to become fublime; whilft the nervous action in fuch
as have exquifite fenfibility will be fo much increafed as
often to produce difagreeable feeling. Modification of the
nitrous oxyd by oxygen or common air will probably
enable the moft delicately fenfible to refpire it without
danger, and even with pleafurable effects; in it's pure
form the moft robuft are unable to refpire it with fafety
for more than five minutes. Hyfterical affection is occa-
fioned by it, probably only from the ftrong emotion pro-
duced deftroying the power of the will.

The quicknefs of the operation of the oxyd will pro-
bably render it ufeful in cafes of extreme debility, pro-
duced by deficiency of common exciting powers; and
perhaps when mixed with oxygen or common air, it may

be ufed to recover perfons apparently dead from fuffoca-
tion by drowning or hanging, as by it's immediate oper-
ation the tone of the irritable fibre is increafed, and as
exhauftion rarely follows the violent mufcular motions
fometimes produced by it, it' may be of ufe in fimple
mufcular debility. As it appears capable of deftroying
phyfical pain, it may be of ufe in furgical operations
where no great effufion of blood takes place.

From the ftrong inclination of thofe who have been plea-
fantly affected by the gas to refpire it again, it is evident
the pleafure produced is not loft, but that it mingles with
the mafs of feelings, and becomes intellectual pleafure or
hope. The defire of fome acquainted with the pleafures
of nitrous oxyd has been fo great, as to induce them to
breathe with eagernefs the air remaining in the bags after
the refpiration of others.

As hydrocarbonat acts as a fedative, and diminifhes
living action as rapidly as nitrous oxyd increafes it, it
would follow, that by differently modifying the atmo-
fphere by means of this gas and the oxyd, we fhould be
in poffeffion of a regular feries of exciting or depreffing
powers applicable to every deviation of the conftitution
from health; but the common theory of excitability is
moft probably founded on a falfe generalization. The
modifications of difeafed action may be infinite and fpe-
cific in different organs; and hence out of the power of
agents operating on the whole of the fyftem.

Pneumatic chemiftry in it's application to medicine is
an art in infancy, weak, almoft ufelefs, but apparently
poffeffed of capabilities of improvement. To be ren-
dered ftrong and mature fhe muft be nourifhed by facts,
ftrengthened by exercife, and cautioufly directed in the
application of her powers by rational fcepticifm.

Approximations to the compofition and weight of the

aëriform combinations of nitrogen at temperature 55° and atmofpheric preffure 30.

		100 Cubic Inches.		Grains.		Nitrogen.	Oxygen.
		Nitrogen		30.04			
		Oxygen		35.06			
Nitrogen	With Oxygen.	Atmofpheric air	weigh	31.10	100 Grains are compofed of	73.00	27.00
		Nitrous oxyd		50.20		63.30	36.70
		Nitrous gas		34.26		44.05	55.95
		Nitrous acid		76.00		29.50	70.50
						Nitrogen.	Hydrogen.
	With Hydrogen.	Ammonia		18.05		80.00	20.00

Haller's Elementa. Phyfiol.—Statical Effays, by Stephen Hales, M. D. F. R. S. Hæmaftaticks. 2 vols. London, 1733.—Mayow Opera omnia Medico-Phys. Oxon. 1674.—Mémoires fur l'Irritabilité, confiderée comme Principe de Vie dans la Nature organifée, par M. Girtanner. Journ. de Phys. 1790. f. 2. p. 139, and f. 1. p. 422.—Lettre de M. Fontana, à M. le Duc de Chaulnes, ibid. 1783. f. 2. p. 262.—Lettre de Fontana, à M. Murray, fur la Phlogiftication de l'Air dans les Poumons, ibid. f. 1. p. 447. 1783.—A Philofophical Enquiry into the Caufe of Animal Heat, &c. by P. Duguid Leflie, M. D. London, 1778.—Experiments and Obfervations on different Kinds of Air, &c. by Jofeph Prieftley, L. L. D. F. R. S. vol 3. p. 348.—Obfervations on Refpiration, 1790. Birmingham.—Connection of Life with Refpiration, by E. Goodwin, M. D. London, 1788.—Gren, Ann. de Chimie. tom. 24.179 7.—Experiments and Obfervations on Animal Heat, &c. by A. Crawford, M. D. F. R. S. Second

edition, London, 1788.—Experiences fur la Refpiration animale dans la Gas dephlogiftique, par M. le Comte, de Morozzo. Journ. de Phys. 2 tom. p. 102. 1784.— Mémoire fur la Chaleur, by Meffrs. Lavoifier and de la Place. Mém. de l'Acad. de la Combuftion & de la Refpiration. 1780.—Premier Mémoire fur la Tranfpiration des Animaux, par A. Seguin et Lavoifier, ibid. p. 611, an. 1790.—Mémoire fur la Combinaifon de l'Oxygene avec la Carbone & l'Hydrogene du Sang, fur la Diffolution de l'Oxygene, &c. par M. Haffenfratz. Acad des Scien. Jan. 29, 1791.—A Differtation on Refpiration, by Dr. Menzies, tranflated from the Latin. Edinburgh, 1796.—Mémoire pour fervir à l'Hiftoire de la Refpiration des Poiffons, par M. Brouffonet. Mem. de l'Acad. p. 174. An. 1785 —Davy on Refpiration, in Dr. Beddoes' Medical Contributions. Briftol, 1799.— Obfervations Chimiques et Phyfiologiques fur la Refpiration des Infectes et des Vers lués à l'Acad. 1791, par M. Vauquelin. Annal. de Chimie. p. 273. tom. 12—Refearches Chemical & Philofophical, chiefly concerning Nitrous Oxide or Dephlogifticated Nitrous Air, and it's Refpiration, by Humphry Davy, London, 1800.

Animalization. This is a procefs which the animal machine makes ufe of to convert vegetable matters taken into the ftomach for the fake of nutrition into animal matter; and *affimilation* is the tranflation of alimentary fubftances, whether produced from the vegetable or animal kingdom, into fuch a ftate as renders them fimilar to the different parts of which they are to become a conftituent part. *Animaliza-tion. Affimila-tion.*

Thefe proceffes are fuppofed to be brought about by a chemical action; and perhaps amongft all the operations which take place in the animal economy, there is no one that refembles the chemical action more than that which *Suppofed to be chemical proceffes.*

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brings about the fucceffive changes aliments undergo, from the inftant they are received into the ftomach to the period at which, after having traverfed the organs of refpiration, they only form a part of one homogeneous fluid, the blood, in the fyftem of circulation, which is deftined for the nourifhing and the repairing of the different parts of the animal body. This converfion of aliment into an animalized fluid, afterwards deftined to form the various folids and fluids, is undoubtedly one of the moft beautiful, fingular, and interefting fubjects the living animal machine can offer to the inveftigation of the chemical phyfiologift, and is one of thofe which has always appeared to philofophers the moft myfterious to conceive, and the moft intricate to unravel, of any of the operations that animal life prefents.

It is but a few years ago fince it was even forefeen that the fcience of chemiftry would ever be able to furnifh any thing that could explain the operation of this function, by which the fucceffive and uninterrupted reproduction of all the parts of the body is brought about. It was neceffary that the nature of the atmofpheric air fhould be underftood, the office of refpiration be known, and the analyfis of animal matter and it's effential difference from vegetable matter fhould be clearly indicated; thefe points being once determined, there was much lefs difficulty in concluding in what confifted the affimilation of aliments, and this has been effected by the new fyftem of chemiftry; but it will be neceffary firft to give an account of the idea the defenders of the old fyftem had conceived of animalization, in which phlogifton formed as ufual a confpicuous part.

Opinion of Ker.

Ker, the ingenious author of the Dictionary of Chemiftry, appears to have formed his idea of animalization from Macquer, who confidered the converfion of vegetable matters into animal to be principally effected by

means of a fermentation, or the beginning of a long and unobfervable putrefaction, and which originated in the conjectures of Hippocrates and Empedocles.

This chemift has, however, greatly enlarged the plan, and improved the hypothefis of his predeceffors. He is of opinion, that when vegetable fubftances are received as food into the bodies of animals, the changes they undergo, and elaboration they fuffer by the animal powers, is a chemical procefs, which procefs appears to be *a con-* Is an inci-*tinually commencing putrefaction, continually checked and* pient putre-*fubdued*. The figns of this commencing putrefaction, he affirms, are the expulfion of fixed air, the black colour the venous blood acquires, the more difengaged ftate of phlogifton in animal bodies than in vegetables, whence they receive their food, their greater putrefcency, their difpofition to give in great quantity volatile alkali by diftillation, and phlogifticated air by addition of nitrous acid, which fubftances are known to be products of putrefaction.

This putrefcency, however, appears to be confined within limits, during life, contrary to the known tendency of animal matters deprived of life, which haften rapidly to putrefaction; that the vital counteracting caufes by which the natural tendency of *animal* matters to putrefaction is continually checked, is owing, in fome meafure, to the frequent indigeftion of frefh food, efpecially of vegetables; but as many animals are known to live folely on animal food, and this often in a putrid ftate, whilft they enjoy health and foundnefs, there muft be another principal caufe to be equivalent to fo great and uniform an effect, which this chemift affirms to be the *abforption of air by the lungs*. It is obferved, that the expulfion of pure air in the form of fixed air, and of a difengaged phlogifton in the form of inflammable gas, are the moft confiderable phenomena in refpect to quantity and dura-

tion, which appear in the putrefactive procefs. In the fame manner, the expulfion of pure air in refpiration, in the form of fixed air, and the confequent predominancy and difengagement of phlogifton in the body, is the actual ftate of the animal procefs. If this predominant phlogifton were not conftantly combined with the pure air, which is abforbed by the lungs in refpiration, it would proceed as it does in the putrefaction of matters not in living animals, *i. e.* it would form inflammable gas, and phlogifticated air, and act as a ferment in haftening the putrefactive diffolution. The very remarkable effect of inflammable gas in promoting the putrefaction of animal bodies immerfed in it, is fhown by an experiment defcribed by Sage in the Mem. de l'Acad. Roy. des Sc. à Paris, An. 1784; and although it is probable the difengaged phlogifton would, if not combined with infpired pure air, occafion death by fome immediate action on the nervous fyftem, yet the livid hue obferved in men in afphyxy, or fuffocation from foul air, fhows that the blood fuddenly fuffers a chemical alteration.

Difengagement of phlogifton.

Pure air then, according to Ker, is no fooner abforbed than it gives immediate figns of counteracting the firft indications of putrefcency, which appear in the dark colour of the blood brought into the lungs, by inftantaneoufly changing this colour to a vivid hue. This change of colour from a dark red or black to a florid red, exactly correfponds with the known effects of the different fluids upon the colour of blood. For a dark livid colour is produced by expofing blood out of the body to inflammable gas, fixed air, or phlogifticated air, and a florid red hue is given to blood by pure or atmofpherical air. The experiments which have been made by expofing blood to pure air, befides prove, that this fluid has a remarkable power of abforbing this air. Putrefying fubftances have the fame power; for Dr. Prieftley obferved, that they

Putrefcency oppofed by pure air.

diminished the bulk of the mass of air to which they were exposed, notwithstanding substances in that state emit fixed air and inflammable gas. It is by means of this constant counteraction of the putrefcency of the blood, according to Ker, that opportunity and time are given for various other gradual changes, combinations, and decompositions to take place; in consequence of which changes the different animal fluids may be supposed to be formed. Thus he conjectures the red part of the blood is first formed in a great measure from the chyle, both being of an oleaginous nature; but with this difference, that the oily matter in the chyle is imperfectly mixed, and consequently gives the usual opake whitenefs mixtures of oil and water generally exhibit; whereas the oil in blood is more perfectly combined with earthy matter, probably by absorption of pure air in refpiration. It may be remarked, that these two animal liquors, the chyle and the red blood, contain particles visible by means of the microscope. But a more conclusive operation has been taken notice of, viz. that one of the moft immediate effects of famine is to diminish the proportion of the red blood. The superfluous oil of the chyle is separated and depofited in proper cells, without undergoing much alteration. For the tallow of animals which live on vegetables retains the properties of vegetable oils, particularly that of making *hard* foap with mineral alkali; whereas the greafe of carnivorous animals, and the oil of fifh, feem altered by the animal procefs, and are capable only of making a *fofter* foap. The red particles of the blood, having a fufficient proportion of phlogifton in their composition, are more difpofed than the other parts of the blood to putrefcency: accordingly, as their phlogifton gradually leaves them, principally to form the fixed air extricated by the lungs, their proportion of the other elements increases, *i. e.* they are gradually refolved into a

Formation of different parts.

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compound containing lefs phlogifton, but more earth, water, and air; which compound this chemift conceives to be the coagulable part of the ferum, which being foluble in water, mixes with the watery particles received with the food, and forms the ferum. In confequence of the dephlogiftication of the red blood, by which it is thus fuppofed to be converted into the coagulable matter, this matter poffeffes lefs putrefcency, has even fome acefcent tendency, and when diftilled, leaves a more earthy and lefs inflammable coal. Some particles of this matter are denfer and more eafily coagulable than others, and thofe which coagulate with the leaft cold, have been called the *fibrous part* of the blood, and are found to invelop the red particles, when blood let out of the veins is cooled. As this matter is thus formed by the decompofition of the red blood, in the circulation, the more the force of the circulation is increafed, the more the particles in the blood will be agitated and brought into contact, the more this decompofition will be accelerated, and the larger quantity of this coagulable matter will be formed, a good deal of which will be of the denfer kind, till the continuance of the fame caufes refolves it into other fluids lefs denfe. For this matter alfo, according to this chemift, although lefs putrefcent than the red blood, neverthelefs undergoes gradually it's peculiar changes and decompofitions, by which more of it's phlogifton is evolved, and the remaining elements, earth, air, and water, being in greater proportion, approach more to a faline ftate, and at laft are excreted principally in the form of phofphoric falts, with bafes of calcareous earth, fixed and volatile alkali; which accordingly appear in the urine and other excretions, efpecially after an increafed circulation. As the changes of the blood are progreffive, the juices muft, at different times, affume a variety of forms, and in thefe different ftates, they may be fecreted

by organs fitted for their peculiar feparations by the diverfity of the diameters of the fecretory veffels, as fome authors have conjectured with much plaufibility, or other appropriated mechanical ftructure.

The *gluten* of the flour of wheat feems to be fimilar to the more denfe coagulable matter of the blood in it's texture, it's degree of folubility in water, and in the products it yields by expofure to diftillation, viz. volatile alkali and phofphorus. In fome animals, as the teftaceous, a part of the earth in their compofition is entirely feparated from the other elements, and appears in it's proper ftate, forming together with fome portion of animal gluten the fhells of thefe animals. A fimilar kind of glutinous fubftance is formed by the fpontaneous decompofition, to which oily vegetable acids, as cream of tartar and common vinegar, are fubject. The tenaceous cruft then formed poffeffes the fame texture and chemical qualities as animal or farinaceous gluten. Laftly, the *cafeous* part of milk poffeffes the fame properties. In thefe feveral animal and vegetable glutens, the earth appears to be the prevalent element in the compofition, and their formation feems to conftitute one of the more advanced ftages in the gradual changes which take place in organic bodies. Such is the opinion of this learned chemift refpecting the procefs of animalization.

The new doctrine of chemiftry, fo inimical to the phlogiftic fyftem, has equally changed the method of explaining the phenomena of animalization, as well as that of other proceffes, and has fubftituted in it's place a theory that is much better fuited to the facts that have been collected upon that vital function, and to the analyfis of the fubftances that are it's objects, than what could have been done by the old theory.

From the experiments of Berthollet, we are indebted for the difcovery that it is principally by the prefence of

azot that the matters of the animal kingdom differ from
the vegetable ; it is therefore neceffary firft to know, in
explaining this fubject, by what means azot is found
more abundantly in animals, and this being once ac-
counted for, will form the bafis of our knowledge on
animalization. It may be eafily conceived that the diffi-
culty of acquiring this knowledge can only relate to thofe
animals that live on vegetable matter, for the origin or
the fource of that principle in thofe animals that feed on
the fame food as themfelves are compofed of, *i. e.* on
animal food, needs no invefligation.

For the attempt to explain the function of animaliza-
tion upon antiphlogiftic principles, we are indebted to
Halle, who has collected a number of new truths from
the labours of modern chemifts, and formed a theory on
the influence of the air in the operation by which the
aliments are converted into animal fubftances.

Having introduced his fubject with fome account of
the analogies that fubfift between vegetable and animal
matters, particularly between vegetable gelatin, and glu-
ten and animal gelatin, and fibrin, which are the prin-
cipal parts, and thofe which form with the phofphat of
lime the moft univerfal bafis of animal folids ; he goes on
by obferving, that there is a character of refemblance much
more important, and for the knowledge of which we are
principally indebted to Berthollet. It is, that all vege-
table and animal fubftances ferving us for food, and all

Analogy
between
vegetable
and animal
fubftances.

of thofe compofing our own folids and fluids, except a
very few, have one common bafis in their compofition,
which is differently combined, according to the diverfity
of thefe fubftances, and which is fufceptible of changing
their combination by a great number of different opera-
tions. This common bafis is that of the oxalic acid, *i. e.*
that fubftance which combined with oxygen, the princi-

Have one
common

ple that forms acids, gives rife to the acid, formerly called

faccharine acid, but now known by the name of *oxalic* bafis, the oxalic acid.
acid.

This bafis is that of all nutritive fubftances in general. The faccharine matter, the mucilage, the fecula, the gelatinous and mucous juices of vegetables, the vegetable gluten, a great number of vegetable acids, and likewife all animal mucilages ; their jellies, their fibrous part, their albuminous fubftance, and the cafeous part of milk, have all of them the fame principle for a bafis, which is that of the oxalic acid. This is proved by the nitric acid.

Likewife, the fat oils of vegetables, the butters, and the animal fats, the analyfis of which does not afford exactly the fame refult, appear, as is attefted by feveral phenomena of the animal economy, to be capable of being transformed into this bafis, and from the knowledge that has been acquired on the ftate of this ifolated oxalic bafis, there is reafon to prefume, that if there be not a perfect identity between it and the fat oils, there is only a difference in the combination, the nature of which Lavoifier appears to have nearly determined: this chemift afferts, that this bafis, as well as the oils, is formed of hydrogen and carbon, but both in the ftate of oxyds, and which confequently is the point of refemblance between all fubftances capable of affording nourifhment.

Such is the analogy. As to the difference, we are Difference between them. indebted for this part of the analyfis to Berthollet, who, purfuing the fteps of Bergman and Scheele, has been able to demonftrate the different principles to which the oxalic bafis is combined, both in animal and vegetable fubftances, whilft Fourcroy has likewife contributed to augment the knowledge this important analyfis has procured us.

The oxalic bafis combined with carbon in vegetables, with azot in animals.

It is demonftrated by the labours of the above chemift, that in all thefe fubftances, the oxalic bafis, without changing it's nature, is more particularly combined with two different principles.

1. With the principle of charcoal or *carbon*, the fame which, when combined with the bafis of vital air, forms carbonic acid.

2. With one of the conftituent principles of vo-latile alcali, or *azot*, which forms the bafis of azot gas.

The firft, or carbon, is more abundant in vegetable fub-ftances; the fecond, or azot, is found in greater propor-tion in animal fubftances. Thofe which contain car-bon in great abundance, and little or no azot, are like-wife thofe which in their fpontaneous decompofition give early figns of acefcence; thofe, on the contrary, which contain a great portion of azot, become fuddenly alcalefcent.

Thus when vegetable fubftances become animalized, and when our aliments, which are in general lefs anima-lized, than ourfelves, are affimilated to our own fubftance, it may be faid the change which then takes place in them confifts for the moft part in their oxalic bafis combining with a greater proportion of the bafis of azot gas, or *azot*; whilft on the contrary, it lofes a part of the principle of charcoal, or *carbon*, to which it might be united: on confidering, therefore, that on analyfis, if either the one or the other of thefe princi-ples be feparated from the oxalic bafis to which they are united, the combinations into which they pafs, almoft always give rife to fome elaftic fluids; it will be readily conceived, how much the confideration of thefe fluids in the animal economy ought to attract the attention

of phyficians, and how it may facilitate the knowledge of the moft important phenomena of our functions.

Halle having compared, in the manner above mentioned, the different fubftances that enter into the compofition of our aliments, and into that of our organs, which he calls the firft order of facts, continues the fub- First and fecond order of facts. ject by the fecond order of facts, comprehending

1.   The ftate of the elaftic fluids contained in the alimentary canal.

2.   The changes the air undergoes during refpiration.

3.   The alterations it undergoes in it's contact with the fkin.

With refpect to the *firft*. This chemift informs us, the obfervations which Jurine of Geneva made on the ftate of the elaftic fluids contained in the inteftinal canal, were formed from fome experiments made on a ftrong hearty perfon who had died fuddenly during a cold night, and which were compared with thofe the diffection of feveral other bodies offered, under different circumftances, but who died in good health.

Thefe experiments prefent thefe remarkable refults, that of the elaftic fluids contained in the inteftinal canal, 1. The refpective proportion of vital air always diminifhes progreffively from the ftomach to the great inteftines : 2. The refpective proportion of azot gas always increafes progreffively from the ftomach to the great inteftines : 3. The proportion of the hydrogen gas in general augments from the ftomach to the fmall inteftines, and diminifhes from them to the great inteftines : 4. The proportion of carbonic acid gas is the moft variable of all in different fubjects; it was very ftrong in the ftomach of the fubject that died fuddenly, but very weak in the reft of the inteftinal canal : 5. It appears that there exifts a little alcaline or ammoniacal gas in the canal of the laft inteftines.

Such is the refult of thefe experiments, made by lime water and the nitrous gas.

With refpect to the *fecond*, it was remarked by Prieft-ley, that refpiration produced azot gas. Lavoifier and de la Place proved, that during that procefs, carbonic acid gas was formed at the expenfe of the vital air, and the experiments were repeated by Jurine. Hence it appears that refpiration alters the atmofpheric air in three manners. 1. The portion of vital air, which makes a little more than one quarter of this fluid, is fenfi-bly diminifhed. 2. Carbonic acid gas is formed in proportion to this diminution of vital air. 3. A new quantity of azot gas is formed, which ought not to be at-tributed folely to the change in proportion between the two conftituent parts of the atmofphere, but which is, in reality, an additional quantity. Thefe alterations in the refpired air do not all take place in the fame inftant of time. The two firft, which are abfolutely fimulta-neous, firft take place, as they depend entirely upon each other. When the portion of vital air in the refpirable air diminifhes, the quantity of carbonic acid produced by refpiration diminifhes likewife ; but on the contrary, the difengagement of azot gas progreffively increafes, and augments the more, as there is lefs carbonic acid formed, fo that the firft portions of vital air appear to be employed in difengaging the carbonic acid, whilft the laft are difengaging the azot. This effect not only takes place in the ordinary atmofpheric air, which naturally contains more than two thirds of azot gas, it equally takes place in vital air, where the production of azot gas can only be the product of refpiration. It has like-wife been obferved, that in the action that finifhes di-geftion, the refpired air received a greater proportion of car-bonic acid, and on the contrary, in the action of fever, it received a greater proportion of azot gas.

Lastly, with respect to the *third*, Jurine has put it out of all doubt, that during the contact of the skin with the external air, carbonic acid is formed, and that more is formed in proportion to the greater activity of the functions of the cutaneous organs. When the experiments of Jurine are compared with the manner in which Ingenhousz made his observations on the same subject, it is easily perceived how the results obtained by these two philosophers may be perfectly reconciled, and upon what the difference depends that exists between their conclusions. It is evident that to the manner in which Ingenhousz made his experiments the disappearance of the carbonic acid was owing.

3. Halle, after having thus cited the above general facts, lays down the consequences respecting the assimilation of the aliment. He observes, that after having remarked, that the oxalic basis, the common principle of almost all nutritive substances, as well as of those that compose our organs, is principally combined, in the one, with the basis of carbonic acid or carbon, in the other, with the basis of azot gas, or azot, and that the proportion of this last formed one of the principal characters of animalization ; the next circumstance is to consider the manner of their separation.

It is well known there are different ways of separating these two principles from the oxalic basis with which they are united, whether in our aliments or in our organs. That this separation is principally brought about by the acid of bodies containing the basis of vital air, viz. oxygen.

In the common chemical analysis of substances the nitric acid is used to furnish this basis with more facility.

In the grand operations of nature it is furnished by the atmospheric air, and by water. Wherever it is the atmospheric air that disengages the carbon, carbonic acid is formed, or if it disengages the azot, azot gas. Wherever it is water that furnishes the basis of vital air, hydrogen

gas is difengaged; and wherever hydrogen is difengaged at the fame time as azot, and combines with it, ammonia or volatile alkali is produced.

The feparation being well underftood, the next is to examine what paffes in the human body.

Proportion of vital air in the inteftines. In the inteftinal canal the proportion of vital air diminifhes fucceffively from the ftomach to the extremity of the inteftinal canal, and at this extremity there is no trace of it; thus the vital air, or it's bafis oxygen, forms combinations in this paffage, and what is the confe **It's combinations.** quence?

In the ftomach, where the aliments ftill poffefs their former properties and mix with the juices, of the nature of which there is much incertitude, a portion of *carbonic acid* is difengaged; the principle, carbon, that unites with the vital air to form this gas, appears to come from the aliment, and if the proportion be not conftant, it arifes from the aliments not always being the fame.

In the fmall inteftines into which the bile, one of the known humours that carries the moft evidently the animal character, flows with feveral other fecretions, and where the aliments, intimately penetrated with thefe humours, form a very liquid mafs, azot and hydrogen gafes are difengaged. One part of the matters contained in this canal being of the number of thofe that contain the bafis of azot gas or azot, may confequently give rife to the extrication of the azot gas, and thefe fame matters forming a heated mafs and in a liquid ftate are the beft adapted to bring about the decompofition of the water. The water being thus decompofed gives rife to inflammable gas, and at the fame time furnifhes the mafs of animal juices and aliments with a portion of the bafis of vital air or oxygen, which forms a combination whilft the azot efcapes.

Laftly, in the great inteftines, where the excrementitious mafs, by it's odour and products, announces the animal character, the quantity of azot gas increafes, but

the inflammable gas diminishes a little, either because the matters being less liquid favour less the decomposition of water, or because a part of the hydrogen combined with the azot forms ammonia or alkaline gas ; on the contrary, in certain diarrhœas, the air let loose from the rectum bearing an hepatic odour, is a proof that a very large proportion of sulphurated hydrogen gas is formed in the great intestines. But these matters being then more liquid, the decomposition of the water continues to take place beyond the small intestines.

Thus in the alimentary canal the vital air, whether it be free and arising from the atmospheric air swallowed with the aliments, or disengaged afterwards by the decomposition of water, combines both with the animal secretions and with the aliments confounded with them in the intestinal canal, and at first separates from the alimentary matters a portion of their carbon, with which it unites to form the carbonic acid, afterwards disengaging azot from the intestinal secretions, it favours it's combination with the alimentary matters that receive it in *lieu* of the *carbon*, a portion of which they have lost. In this manner the aliments that nourish us commence their incipient animalization, the degree of which, Halle is of opinion, might be estimated, if the nature of the chyle, which is the result, was perfectly understood.

4. Conclusion. It appears therefore to this chemical physiologist, from what has been above stated, that a great part of the process producing the assimilation of aliments, is performed in the *intestinal canal*, in the *organs of respiration*, and upon the *surface of the skin*. That in these three organized parts, the atmospheric air, and particularly the vital part of this air, is the principal instrument of the combinations by which the assimilation is brought about; that it probably acts by taking away from the alimentary matter a portion of it's carbonic

principle, and by facilitating it's combination with the overplus azot of the animal humours, and confequently, that in this common operation, the execution of which is divided between three different organs, but founded in all upon the fame principles, a reciprocal change takes place at the fame time, as well in the fubftance of the aliment as in that of the animal humours; by which the one being animalized, and the others lofing, as it were, the excefs of their animalization, all of them are brought to the fame point, and appear mutually affimilated.

Imperfec-
tion of this
theory.

This chemift, in delivering his theory to the world, does not prefume to think that it explains the formation of all the products of animal affimilation, he allows, it neither accounts for the production of the phofphoric falts, nor that of the fat matter analogous to fpermaceti, found by Fourcroy in the liver and bile; nor does it explain the manner in which the other animal products are modified, on which modern chemiftry has at prefent caft no light; hence it is incomplete. Such is the manner by which Halle has attempted to explain the mechanifm of the affimilation of aliments, and of the change they undergo in their nature, and in which it is to be obferved, that although he has made ufe of the difcoveries of Scheele, Bergman, Lavoifier, Prieftley, and Berthollet, yet he is one of the firft that has embraced fo great an extent of operations at the fame time refpecting the animal functions, and that it was impoffible from the prefent ftate of facts, that fo difficult a problem as that of animalization could be refolved by the few materials he was in poffeffion of.

Obferva-
tions of
Fourcroy
upon it.

Fourcroy, who had perhaps a better opportunity of becoming acquainted with facts than Halle, and who had the advantage of later difcoveries, has made fome reftrictions and obfervations upon the hypothefis of the latter. He thinks it neceffary to obferve, that in refer-ring all fubftances compofed of the vegetable and animal

kingdom to what Halle calls the *oxalic bafis* or *oxalic radi-cal*, this philofopher could only have in view the fixing a ftriking analogy between all fubftances; but as the confidering of it in this light without fome modifications might lead to errour, it is neceffary to explain how far the truth is able to carry us.

By the oxalic bafis or radical is underftood a matter compofed of hydrogen and carbon, which when united with a large proportion of oxygen, gives rife to the oxalic acid, and which plays the fame part in this acid as ful-phur, phofphorus, charcoal, or arfenic does in the ful-phuric, phofphoric, carbonic, and arfenic acids. If all animal and vegetable matters can be confidered as the oxalic bafis, it can only be as containing the *carbonated hydrogenous* combination conftituting this bafis. But it would be erroneous to fuppofe that this *carbonated hydro-gen* is equally compofed, as to the proportion of thefe two principles, and confequently equally ready to form the oxalic acid on the addition of oxygen, in all thefe mat-ters.

The combination of hydrogen and of carbon that forms the general bafis of organized fubftances is not homo-geneous in all of them; it differs either in the proportion of one or other of the primitive principles, or in the addition of a greater or lefs quantity of azot, or laftly, in the proportion of the oxygen it already contains; hence to be converted into oxalic acid, it is not fufficient con-ftantly to add oxygen and an equal quantity of oxygen to it. For the one it is neceffary that a certain proportion of hydrogen or carbon be difengaged, according as the one or the other exceeds the quantity that ought to form the true oxalic radical; for the other to difengage a por-tion of thefe two principles; for a third order of thefe fubftances to take away or feparate at firft the azot that does not appear to enter into the oxalic acid. Thus,

when by means of the nitric acid, the gums, fugar, or ftarch, are converted into oxalic acid, much carbonic acid is difengaged, becaufe thefe matters contain much more carbon than is neceffary for the oxalic radical; when by means of the fame nitric acid the fame procefs is applied to the oils, butters, fats, refins, &c., a great deal of hydrogen and carbonic acid gafes is difengaged, a proof of there being more hydrogen and carbon than are neceffary for the oxalic radical; laftly, when the nitric acid is made to act on vegetable gluten, elaftic gum, mufcular flefh, and all other animal matters, thefe matters are not converted into oxalic acid until they have given out azot and carbonic acid gafes, becaufe they contain azot that does not enter into the formation of the oxalic acid, and more carbon than this acid has need of: and it is in this manner the nature of the oxalic radical is to be looked upon, as far as Halle conceives it to exift in all matters confidered as aliments, whilft what has been faid upon the fubject ought only to refer to the following propofition, viz. that all alimentary matters contain that, which, by the addition of oxygen, forms the oxalic acid.

On the fe-
cond part.

Since the facts related by Halle on refpiration, that function has been much better inveftigated by the united labours of Lavoifier and Seguin. During refpiration, water is undoubtedly formed, and there is a difengagement of hydrogen as well as of carbon from the blood. This effect refembles that which takes place in all vegetable matters expofed to the air. It even appears to Fourcroy, that hydrogen burns more eafily than carbon, at leaft in making the analogy refpecting vegetable fubftances. He allows, however, that this formation of carbonic acid and water during refpiration is not as yet fupported by any pofitive experiments. There are even fome who think that the vital air is wholly abforbed by

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the lungs, that in the courfe of circulation it is by degrees converted into carbonic acid, and that it is afterwards evacuated by the lungs. This opinion, it is evident, is very different from that which explains the formation of the carbonic acid to be effected by the pulmonary organ, owing to the carbon difengaged from the blood afterward uniting with the atmofpheric oxygen. The obfervation upon what paffes during the refpiration of the great grafshopper (locufta vermivora of Geoffroy) by Vanquelin, appears to authorize this laft opinion. He found a canal which conducts the air immediately from the trachea to the ftomach, and he believes with much probability, that the air ferves to the affimilation of the aliments. If the immediate combination with the mafs of aliments or of the chyle be neceffary to complete digeftion, or to affimilation, as fome facts appear to indicate, and as feveral philofophers are of opinion, it appears that the vital air really penetrates the lungs and combines with the blood, which at the fame time exhales carbonic acid. To conclude, it is fufficient for the conclufions drawn by Halle in whatever manner thefe things are effected, that there be fome means during refpiration of exhaling carbon. Lavoifier has confirmed, by his laft experiments on refpiration and tranfpiration, the refult of thofe of Jurine, and it appears inconteftibly, according to Fourcroy, that the procefs which takes place on the fkin affords a fimilar phenomenon to what paffes in the lungs, i. e. a formation or a difengagement of carbonic acid. It may be poffible that three effects concur at the fame time in this procefs of affimilation, for which it is proved that the pulmonary and cutaneous organs are in a great meafure deftined. Perhaps there is a feparation of carbon and hydrogen from the lungs ; perhaps oxygen may penetrate at the fame time, which uniting by degrees with the carbon of the blood during refpiration, after-

ward flows out in torrents through the veffels of the whole furface of the fkin. (*Vide* refpiration.)

On the third part. Fourcroy is of opinion that Halle, in attributing the beginning of affimilation brought about in the ftomach and inteftines in great part to the decompofition of water, cannot fupport his conjecture; and indeed, it is only upon the prefence of carbonic acid, hydrogen, and ammoniacal gafes in the cavity of thefe vifcera, that he offers it. It is neceffary to remark, that it is founded upon an obfervation made by Jurine only on one cafe, and that it would not be reafoning with much precifion to apply it as a general rule. It may be prefumed, that the exiftence of the gafes is nearly the fame in the courfe of the alimentary canal of all fubjects with that which Jurine found in his fubject; but there is no proof that the production of thefe inteftinal gafes are owing to the decompofition of water, nor even that the difference of thefe gafes in the different parts of the canal depends upon the ftate of the water.

Fourcroy's explanation. Fourcroy is of opinion, that the primary effects of digeftion, which ought not to be confounded with thofe of affimilation, properly fo called, may be explained without having recourfe to the decompofition of water. Four principal phenomena take place in the aliments during their refidence in the ftomach and inteftines.

1ft. The aliments are foftened and diffolved into a kind of homogeneous pulp in the inteftines.

2d. Their character is changed by the gaftric menftruum.

3d. This folution is decompofed in the fmall inteftines by the bile, which feparates the alimentary part from the excrementitious.

4th. The chylous matter is abforbed by the lymphatics in the large inteftines, and the excrementitious matter is forced down, carrying with it the fat and colouring matter

of the bile. The bile conveyed into the blood undergoes a change in the lungs. The aliments themfelves may be the fource of the gafes contained in the alimentary tube.

This chyle being poured into the blood, and mixed with it as the alimentary matters were mixed with the animal fecretions in the inteftines, is then acted upon by means of refpiration. During that procefs, the vital air forms combinations, carbonic acid and azot are difengaged, but both do not appear internally at the fame time. The azot gas only appears when the quantity of carbonic acid formed by the vital air, and mixed with the refpired air, diminifhes in this air the property of difengaging frefh acid from the lungs, which is the cafe when bad air is breathed. Then the azot, which is probably alfo difengaged, but which combined with the chyle in proportion as this loft it's carbonaceous principle, finding no more to combine with, departs with the air in the form of gas.

It is therefore probable that in this cafe the principle of the carbon is furnifhed by the chyle, and the azot by the blood, and that a real exchange is made as in the procefs of digeftion, *i. e.* the chyle, on lofing a part of it's carbon, receives in *lieu* of it the azot feparated from the blood, and by this mechanifm is animalized and affimilated. It may be faid that the blood likewife affimilates itfelf, becaufe without this exchange, which deprives it of an excefs of azot, it would be too much animalized, and at laft become alkalized, which, in effect, always takes place when a long abftinence, or food which is too much animalized, prevents the humours from receiving their neceffary temperature by the mixture of a mild chyle.

It may be afked, if the refpiration would ceafe to pro-

duce carbonic acid gas, in confequence of a long faft, and at laft only produce azot gas, which would feem to be the confequence of this fyftem. Experiments are wanting to anfwer this queftion; but prefumption, and two facts ftated by Jurine, almoft affure the affirmative. The one proves, that in the procefs that follows the digeftion of the aliment, and which is accompanied by a fenfible increafe of heat, and an accelerated pulfe, the proportion of carbonic acid formed by the refpiration in equal quantities of air, is much greater. The other ftates, that in fevers, the contrary takes place, for the proportion of carbonic acid is diminifhed, and that of azot gas increafed.

After this important operation, follows that which is the refult of the functions of the fkin. From the furface of this organ, the vital air likewife difengages a portion of the carbonic principle, with which it forms carbonic acid; and if it be true, as an experiment of Dr. Prieftley appears to prove, although contradicted by thofe of Cruickfhanks and Jurine, that the air which has remained in contact with the fkin appears, on trying it with nitrous, to be meliorated, and to have loft during this contact a part of it's azot gas, the confequence would alfo be, that the humours become animalized in the fkin by a mechanifm analogous to thofe of digeftion and refpiration; at leaft it appears certain, that a difengagement of the carbonaceous principle really takes place in this organ, but the ignorance which covers the real nature of cutaneous perfpiration, ftill involves this fubject in obfcurity. *Vide* Refpiration.

Such are the modifications made by Fourcroy on the fyftem of Halle, and the obfervations which the ftate of the fcience allowed him to make on the procefs of animalization. The facts which have fince been brought to

light, are very few, and are scarcely sufficient to afford any further explanation than what this chemist has given us; before, however, this article is concluded, it will be necessary to mention the little that remains.

It is the opinion of several of the most celebrated che- mists, and particularly of Parmentier and Deyeux, that the different solids and fluids of the body are created by the process of animalization from the remote, and not from the proximate parts, and consequently, that the vital organization does not take from the aliments albumen, gelatin, fibrin, sulphur, phosphorus, soda, lime, or iron, all of which they look upon as compositions, but only their ultimate parts which are necessary for their formation.

Thus, in the blood, the different substances it contains are not extracted immediately from the aliments, since in spite of their infinite variety, this fluid, whatever be it's origin, constantly furnishes the same principles on analysis, and they even appear so necessary to it's composition, as not to be able to exist without them. Hence these chemists think, that it will be useless in future to endeavour to search in aliments and drinks for such of their parts as ought to serve in the formation of the chyle, the blood, bile, &c., or to pretend to give a reason for the transformation of the one into the other, without changing their nature. Before undergoing this transformation, it is necessary for these substances to be exposed to the action of the stomach and intestines, to pass through all the periods of decomposition, and that the gaseous materials, or aëriform fluids arising, undergo a certain fabrication in the different organs, so as to form the various matters of the body, with modifications peculiar to each individual species, according to it's physical constitution, whether healthy or vitiated by some morbific affection.

It has already been afferted, that the remote parts of animal fubftances are reduced to nine, viz. azot, oxygen, hydrogen, carbon, foda, fulphur, phofphorus, lime, and iron, and that the principal difference between animals and vegetables confifted in the prefence or proportion of azot, which the firft contained in fuch large quantity.

It might therefore be concluded, that the grand procefs of animalization confifted in the fixation of azot, and the addition of it as the principal phenomena of animal organifm; but it has been obferved by the lateft phyfiological chemifts, that this phenomenon ought not to be confidered fo much the effect of the fixation of a new quantity of this principle, as the fubtraction of the other principles, by which the proportion of the firft muft be in confequence increafed. It is thus, for inftance, that the function of refpiration, by gradually difengaging a great quantity of hydrogen and carbon, which, by uniting the one with the oxygen to form water, the other with another portion of oxygen to form carbonic acid, muft neceffarily increafe the proportion of azot. A large proportion of this principle being thus accumulated, is ready to be united with more or lefs of the other remote parts in different proportions, to form the various animal fubftances of which a body is compofed.

Humboldt. According to Humboldt, this union by the function of animalization is brought about by the intermedium of the galvanic fluid. Thus the carbon and hydrogen, combined by means of this galvanic fluid, form oils. The hydrogen and carbon, combined with the oxygen by the fame means, form acids. The hydrogen, combined with the azot, forms foda, and fo of the compofition of the reft of animal fubftances, all being formed by the intervention of this fluid, the nature and properties of which are at prefent not underftood, although this chemift looks upon it to be the nervous fluid. With refpect to lime

and iron, he does not confider them as new products in
the animal body, but as furnifhed by the aliments. De
la Metherie, however, as well as feveral other chemifts,
affirms, that the vital power is able by certain organized
parts to form thefe two fubftances as well as fulphur and
phofphorus, and of courfe that they are as well as foda
compofed of remote parts; and this conjecture is ren-
dered very probable by feveral late experiments: thus
Vauquelin found, that the formation of both lime and
phofphorus was effected by the function of animalization
in the hen (*vide* Fœces), and the large quantity of the
phofphat of lime found in milk, and the fhells of all ani-
mals, which cannot be accounted for by any other means,
appears greatly to fupport the hypothefis, that it is the
product of the vital powers; whilft Fourcroy attributes
the abfence of the phofphoric acid in the blood of the
fœtus to the want of refpiration. With refpect to foda,
it is only by the fame way of explanation that it's pre-
fence can be accounted for in graminivorous animals;
and as to fulphur and iron, there is great fufpicion that
they are of the fame manufactory, and fabricated by the
fame powers applied to a different organization. The
fame may be faid of the acids, &c.

Hence it appears, that the organifm neceffary to ani-
malization has the power of reducing aliments to their
remote component parts, and of forming or creating new
fubftances from them; but the fublime procefs that pro-
duces all thefe combinations, the mechanifm by which
thefe tranfmutations, modifications, and affimilations
are fo conftantly executed, and with fo much harmony,
in the organized world, are ftill fecrets which we are not
able to penetrate.

First Part of a Dictionary of Chemiftry, &c. by J. Ker,
F.R.S. & S.A. Birmingham, p. 192. Animalization. 1789.
—Effai de Theorie fur l'Animalization et l'Affimilation

des Aliments, par M. Halle, M. D. Annal. de Chimie. tom. 2. p. 158.—Encyclop. Méthod. tom. 2. Chimie. p. 308. Paris, 1792.—Humboldt, &c. Verfuch einer Phyfifchen Darftellung der Lebenskrafte, &c. extracted in the Journal de Phyfique, p. 32. art. Phyfiologie Animale. tom. xlviii. An 7. de la Republique.

DEATH AND PUTREFACTION.

It was the opinion of most of the ancients, that no-
thing perished during corruption. Pythagoras asserted
there was only a change in the modifications of matter,
and that real annihilation was impossible. Plato relates
it as an ancient tradition, that the living spring from the
dead, and the dead from the living, and that this is the
constant circle of nature. Hippocrates thought that all
animated or living animals, being composed of two prin-
ciples, fire and water, their qualities communicated with
each other, affording that infinite variety which appears
in all the beings of the world ; and that at death nothing
perishes, but the parts only change their form by mixing
or separating from each other. Diogenes, Apollonius,
and Parmenides seem to have held similar opinions.
Aristotle's ideas were not different, for he says, with
respect to substances, that the generation of the one is the
corruption of the other, and *vice versa*.

Among the Roman authors, Lucretius, in his philoso-
phical poem, called The *Nature* of Things, has beauti-
fully described these ideas of the Greeks:

> " Besides, as nothing nature's power creates,
> So death dissolves, but not annihilates.
> For could the substances of bodies die,
> They presently would vanish from our eye ;
> Dissolving, without force, they'd perish all,
> And silently into their nothing fall,—
>
> " If all things, over which long years prevail,
> Did wholly perish, and their matter fail,
> How could the powers of all-kind Venus breed
> A constant race of animal to succeed ?

Or how the earth eternally fupply,
With conftant food, each his neceffity?—
   " But fince the feed's eternal, and the frame
Of bodies, and their union not the fame,
Things may fecure and free from danger ftand,
Until fome envious force fhall break the band,
Thus death diffolves alone, death breaks the chain
And fcatters things to their firft feeds again."

                                   CREECH.

Moderns.
Leibnitz.

Leibnitz, among the moderns, has expreffed fimilar
ideas. All things are compofed of monads, according to
this philofopher, which are fimple, indivifible fubftances;
they are the real elements of nature, and as fuch there is
no fear of their diffolution. There can be no conception
of a fimple fubftance perifhing naturally, but every thing
that perifhes, perifhes by diffolution into it's fimple parts,
and every thing that is formed, is formed by compofi-
tion. Monads, therefore, can only exift or ceafe an in-
ftant, by creation, or annihilation, each monad being in
a continued change or viciffitude. Hence it appears,
that neither the ancients nor Leibnitz, although they had
no idea of the compofition of animal fubftances, ever
thought that death was their extinction, but that they
again revived under new forms and circumftances.

Signs of
death.

Death may be defined the abfence of life, and as it is
of great moment to be able to afcertain it with certainty,
feveral methods have been proved to enable the phyfician
to diftinguifh between it's apparent and real ftate. Beh-
rends and Creve were the firft to prefent to the world
galvanifm as the proper teft; the latter in particular has
made many experiments to afcertain the fact. This me-
thod is remarkable for it's fimplicity and convenience.
Upon any anxiety refpecting a fufpicion of a body being
not dead, a naked nerve is put into contact with a pair of

metallic rods compofed of filver and zinc, and this will refolve the important problem, whether any irritability ftill remains, and confequently whether the recovery of the corpfe be poffible. Humboldt, however, although he rejects this as an infallible guide, is of opinion, that it will afcertain the object to a great degree of probability, and hence recommends it's employment as of great ufe.

The only certain fign of death is putridity. It's pre- Putridity fence never deceives. When the vital principle, or as tain fign of Hippocrates calls it, the vital flame, is extinguifhed in it. animals, their fpontaneous decompofition commences, and this is called the putrid fermentation, or putrefaction. The object of nature in fubmitting them to this procefs, appears to be, to reftore to their primitive elements what life had united, by means of it's different functions, to form a compofite organized body. The matters, therefore, that formed the bodies of animals, are reduced to their primitive fimple ftate, that in procefs of time, by uniting again with life, through organization, they may be employed in the formation of new complex bodies, whether of the vegetable or animal fpecies; and this would feem to be the fpeedieft procefs by which the ultimate parts of bodies, no longer fufceptible of being united to life under one particular form, are tranflated to another. Thus is nature a feries of revolutions, a fucceffion of compofition and decompofition, of production, and of deftruction.

There are a number of authors who have written on Authors on putrefaction, the principal of which are Beecher, Stahl, putrefac- Hales, Pringle, Macbride, Geber, Beaume, and Gardani, fome of which have defcribed with great care many of the phenomena that accompany the putrid change in different bodies; but although they have in fome meafure cleared this fubject of the obfcurity it was in before the time of Bacon, many more experiments and obfervations are neceffary, to give a full and fatisfactory explanation of

the circumſtances attending this ſpontaneous operation of nature. Their great merit has, perhaps, been to point out the way to others who are deſirous of attempting a more minute inveſtigation.

As upon all other ſubjects, there have been various opinions refpecting the nature of putrefaction. Stahl affirmed it to be a real fermentation, and he conſidered it as the end or laſt ſtage which all animal and vegetable ſubſtances are made to undergo by the fermentative proceſſes; and almoſt all the later chemiſts, ſuch as Weigel, Gmelin, Macquer, and Morveau, ſeem to have been of the ſame opinion.

Boerhaave aſſerted that it was not a fermentative proceſs, but that it was eſſentially different from it, and he appealed to well known facts in his ſupport. Scopoli ſided with Boerhaave, forming his deciſion from the ſame circumſtances, viz. that putrefaction diſengages volatile alkali, decompoſes all the fixed parts of organized bodies, and produces nothing but earth, and ſome effluvia, which though moſt diſagreeable, and even poiſons to the human body, yet being imbibed by the earth and vegetable creation, give life to a new race of beings; whilſt, on the contrary, during the fermentative proceſs, the fibrous texture of ſubſtances remain undecompoſed, and the productions are only fixed air, wine, ſpirits of wine, and vinegar. It would appear, however, that Stahl did not look upon putrefaction to be different from the vinous and acetous fermentations, and that they were entirely independent on each other, but only regarded the three as being principal degrees of the ſame fermentative motion by which all compoſed bodies are diſſolved and reduced to the ſame ſtate; hence, that putrefaction was a kind of fermentation or rather the laſt ſtage of that proceſs, beginning with the vinous, going through the acetous, and ending with the laſt ſtage of putridity. It

Stahl.

Boerhaave.

has likewife been alleged, that if it be a fermentation,
it muft neceffarily be a diftinct kind, fince we frequent-
ly obferve it taking place, where neither of the other
ftages had preceded it, which proves that in fome cafes
at leaft, it muft be entirely independant of, and uncon-
nected with them. Putrefaction has likewife been re-
garded as a fpecies of ignition : it is faid that the power
it has of converting every thing into earth, is evidently
performed by an expanfive power, that in confequence of
this, the body firft fwells, then burfts ; vapours are ex-
fricated and fly off, and the particles fall afunder from
each other, which are the very effects the action of fire
produces upon any combuftible body ; hence it is pro-
bable that the agent in the air confidered as the caufe of
putrefaction, is no other than the fire itfelf ; *i. e.* the
ethereal fluid expanding itfelf every where, and that in-
ftead of an emiffion of flame, which ignition is attended
with, putrefaction is accompanied with a production of
azotic gas.

All organized, and particularly animal fubftances, Subjects of
undergo the putrid fermentation; and Leonhardi is of putrefac-
opinion, that a flight acetous fermentation takes place, tion.
previous to it; this may proceed from the gelatin, which
under certain circumftances, as in broth, is faid to be
fubject to the acetous procefs.

The putrefaction or fpontaneous decompofition of Various
animal fubftances, may be divided into as many fpecies trefaction.
as there are chemical agents in nature capable of pro-
ducing it, thus, when it takes place in the open air, it
may be called, *atmofpheric* putrefaction. But when in
confequence of bodies not being expofed to the external
air, a decompofition takes place amongft their component
parts, and new combinations arife, the products are
totally different. In thefe cafes, the principal effect is
their being deprived of their azot ; fuch is the cafe when

bodies are heaped together in the earth, and hence it may be called *terraneous* putrefaction; or under water, giving rise to the *aqueous* putrefaction. In all thefe cafes where the air is excluded, a more or lefs oily mafs is produced. The fame took place during the *internal* putrefaction of the human liver, as defcribed by Fourcroy.

1. Atmo-
fpheric pu-
trefaction.

1. *Atmofpheric Putrefaction.* When an animal fubftance is expofed to the atmofpheric air, fo as to give rife to it's fpontaneous decompofition, it paffes with more or lefs rapidity through the following changes, particularly affecting it's colour, fmell, and confiftence. It becomes of a paler colour, it's confiftence is diminifhed; if it be folid as flefh, for inftance, it foftens, and a ferous kind of matter oozes out, it's colour quickly changes, it becomes relaxed in it's texture, and it's organization is deftroyed; it has a faint and difagreeable fmell, it finks down and is diminifhed in bulk, and it's fmell becomes ftronger and alcaline. If the fubftance be contained in a clofe veffel, the progrefs of putrefaction, according to Fourcroy, feems to flacken at this ftage, and no other fmell but that of a pungent alcali is perceived; it effervefces with acids, and changes the blue of violets to a green colour. If, however, the communication of the air be admitted, the urinous exhalation is diffipated, and a peculiar putrid fmell extends itfelf with great impetuofity, and of the moft infupportable kind. This fmell continues a long time, fpreads every where, pervades every place, and affects the healths of living animals fo as to produce putrid difeafes. This fmell Fourcroy obferves, is connected, and as it were confined by the volatile alcali, which when volatilized, is fucceeded by the putrefactive procefs, becoming active a fecond time, the fubftance fuddenly fwells, is filled with bubbles of air, but foon after fubfides again. The colour now changes, the fibrous texture of

the flesh is scarcely to be distinguished, and the whole is converted into a soft pulpy brown, or greenish matter, of the consistence of poultice, with a faint, nauseous, and disgusting smell, that is very active and contagious. This smell gradually subsides, the fluid portion of the flesh assumes a kind of consistence; it becomes of a deeper colour, and the whole is finally reduced to a friable matter, somewhat deliquescent, which on being rubbed between the fingers, breaks into a coarse dark powder like earth. This is the last state animal substances undergo during this process, for which a considerable time is necessary. For the total destruction of the whole body of an animal, it is said that eighteen months, two or even three years are scarcely sufficient when exposed to the external air.

During the time animal matters are undergoing the above changes of decomposition, their component parts fly off, or form new combinations, either with the vital air of the atmosphere, or by simple attractions between each of their principles, they form unions amongst themselves, giving rise to simple, binary, and even ternary combinations. The products are carbonic acid gas, ammonia, nitric acid, sulphur, phosphorus, hydrogen gas, and the substances it dissolves, azot gas, Prussian blue and heat, which being disengaged by degrees into the atmosphere, diminish in proportion the mass of animal matters, and there remains an earth behind. *Products of it.*

1. *Carbonic acid.* This is disengaged from putrefying bodies, particularly from solid parts, in large quantity. The quantity appears to be in the inverse proportion of the quantity of hydrogen gas extricated, for at first it is in large proportion, and the hydrogen gas in small proportion, but afterwards the contrary takes place. The first product Lavoisier obtained from the fecal matter of a necessary in a putrid state, was these two gases mixed *Carbonic acid.*

together; 11 parts of carbonic acid, and one of azot gas.
The temperature was at 8° or 10° of Reaumur. Priest-
ley has likewise afcertained their proportion and quan-
tity. Having let 4 pennywts. 6 grs. of lean mutton be-
come putrid, he obtained $2\frac{11}{24}$ oz. meafures of gas, of
which $2\frac{15}{200}$ were carbonic acid gas, the remainder hy-
drogen gas. Corvinus long ago obtained a quantity of
elaftic fluid, from putrid fubftances, one of which was
imbibed by water, the other not, they were therefore very
probably the fame gafes.

The carbonic acid has been fuppofed to have already
exifted in animal fubftances expofed to putrefaction, and
to have been only extricated during that procefs; but
Lavoifier found that new fecal matter would not effervefce
with acids, whilft an effervefcence took place with it in
it's old ftate, which certainly is againft this fuppofition:
fome chemifts, and particularly Berthollet have afferted,
that it arifes from the decompofition of the water, that the
vital air unites with a portion of the carbon of the animal
matter, and forms carbonic acid, whilft the other prin-
ciple of the water, the hydrogen, is fet at liberty in the
form of a gas; hence two gafeous fubftances are obtained,
the carbonic acid and hydrogen gafes. There is, how-
ever, fome doubt of this origin of the carbonic acid;
and other chemifts are of opinion the oxygen is fupplied
by the atmofphere, fince there is no extrication of car-
bonic acid, unlefs the fubftances are in contact with the
atmofpheric air. It is in large quantity in the beginning
of putrefaction, at which time it only exifts. It is the
gas that is often fo fatal to people who defcend into
vaults, and thofe places where animal fubftances are left
to putrefy.

2. *Ammonia.* It was long fuppofed that ammonia al-
ready exifted in animal fubftances before putrefaction
commenced, but Berthollet found that when frefh, no

animal matter contained it perfectly formed, and that
when deprived of azot, by the nitrous acid, they no longer
afforded ammonia by any means, particularly by distil-
lation. It has been before observed, that animal sub-
stances contained a large portion of azot, and this ac-
counts for the origin of ammonia; the azot combining
with the hydrogen of the water, (where oxygen, or at least
part of it formed carbonic acid with the carbon,) forms a
union, which being let loose, is the volatile alcali so very
prevalent amongst putrid substances by it's pungent smell.
It is necessary, however, for the formation of this alcali,
that the two principles meet and unite at the time they
are disengaged, and just taking the gaseous form; for if
both the azot and hydrogen were enveloped in their solid
combination, no union could take place, which happens
in those animal matters that have undergone no alteration;
, on the contrary, one of these two principles is developed
without the other, and separates from the matters that
contain it in the form of an elastic fluid, the produc-
tion of this alcali is equally prevented, as is the case when
the nitric acid is used. But by the slow and gradual ac-
tion of putrefaction, or by that of fire increased by de-
grees, as in distillation, the intimate union of these two
principles is accomplished, by favouring their slow and
simultaneous evolution, and by carrying them within the
reciprocal attraction of each other. It is from the same
circumstances perhaps, that Gaber was not able to dis-
cover any ammonia in putrid substances, either in the
beginning of that state, or towards the end, and which
led him to deny the existence of it at these periods of pu-
trefaction. Crell likewise found it was not to be met
with at all periods; he is, however, of opinion, that it's
presence is to be found as long as the putrid smell con-
tinues, whilst Porner affirmed it's presence to be a sign, that
the putrefactive process has arrived at it's greatest height,

and is approaching to an end. From the facts of the pro-
duction of ammonia, it appears that nature, by allotting
to animal fubftances the property of forming this alcali,
has given one of the principal means of their decompo-
fition, and fpontaneous deftruction; for as foon as the
azot feparates to unite with the hydrogen, the bond of
their intimate compofition is relaxed; this alcalefcence
may then be looked upon as a fign of great diffolution
and perfect diforganization, which cannot take place
in animal matters, without bringing on their total de-
ftruction.

Probability
of the for-
mation alfo
of potafh
and foda.

There is great reafon to believe that, befides this al-
cali, the two others, viz. potafh and foda, may be pro-
duced during putrefaction, although their component
parts are at prefent not well afcertained. There is an ac-
count by Morveau, in his experiments on the effects of
different gafes on flefh, that having fufpended a piece of
lean beef in a bottle, filled with nitrous gas, which was
covered with a moift piece of bladder, and well tied, he
found on opening it five years after, that cryftals of nitre
were formed in it; real nitre is likewife found near
privies, as particularly inftanced by Dr. Wall. The for-
mation of the nitrous acid may be accounted for from
the exiftence of it's radical, but that of the *potafh* is dif-
ficult to explain. Thouvenel, who appears to have ob-
ferved a fimilar phenomenon, admits an epoch of *alcalef-
cence* in putrefaction, after that of *acefcence*. The fame
author has obferved, that where putrid fubftances are ex-
pofed for the formation of faltpetre, the *mineral alcali* is
likewife formed.

Nitric acid.

3. *Nitric acid.* It had long been known that the
putrid fermentation was very neceffary to the formation
of nitre, and Kunckel, Vieuffens, and Homberg had
remarked that putrid plood when dried and expofed to
the air afforded it in large quantity. Juncker relates

that Kunckel having let some blood putrefy, until it was reduced to an earth, lixiviated and evaporated the liquor until a pellicle appeared, and obtained from 100lb. of blood, rather more than 5lb. of cryſtallized nitre. But the moſt direct and ſimple experiment was made by the Commiſſioners of the Academy: they put ſome chalk well lixiviated in boiling water into baſkets, and expoſed them to the vapour of putrid ox blood, at about two feet diſtant from each other; when at the end of a few months, the chalk was found to contain four or five ounces of ſaltpetre for each quintal; from which they conclude, that the nitrous acid is produced by the union of the vital and the putrid airs, provided every thing is tranquil, and the atmoſpheric air is renewed by little at a time, and ſlowly. Thouvenel made ſome experiments on this ſubject, by putting into different veſſels air diſengaged from putrid matters, with various aëriform fluids, and into which he had previouſly put ſome alcali or earth, in order to fix the acid, and he found 1. that at the end of a few months, nitrous acid was only formed in that veſſel in which was vital or atmoſpheric air. 2. That chalk always afforded it when expoſed to the mixture, and other ſoluble earths, and alcalis very rarely. 3. That of all animal matters, blood affords it in greateſt abundance, and during the longeſt time. Since the diſcovery of Berthollet, that azot is ſo abundant in animal ſubſtances, and ſince the compoſition of the nitric acid has been found to contain that principle, as one of it's component parts, ſome light has been thrown on this obſcure ſubject; and the formation of this acid is now accounted for by ſome chemiſts, from the vital air of the atmoſphere uniting with the azot, which is extricated in the form of gas from the putrid matter; whilſt others on the contrary, as Fourcroy, allege, that there is a decompoſition of the water, and that the oxygen is furniſhed

by that fluid. It was affirmed by Shaw, that the pro-
duction of this acid was only during the laft ftage of pu-
trefaction. It has alfo been obferved, that it is not a
quick but a very flow putrid decompofition that produced
the greateft quantity of this acid; that a too great degree
of moifture, or too long continued, was hurtful; and
from the experiments of Crell it appears, that a mode-
rate heat, fuch as fpring and autumn, with a change
every fourteen days, or once a month, of the furface of
the putrid matter, and a moift atmofphere, were the moft
favourable to it's generation.

Sulphur.   4. *Sulphur.* According to De la Metherie, this fub-
ftance has been found in feveral places where putridity is
going on, as on the fides of ftalls; and according to
Rochefoucault, it was found cryftallized on the walls of
fome old paffages at Paris, arifing from the effluvia of pu-
trefying fubftances; it has likewife been obferved in the
dung of horfes, and is fuppofed to be the produce of an
incipient putrefaction.

Phofphorus.   5. *Phofphorus.* The phofphorefcent light obferved in
putrid fubftances, and particularly in putrid fifh, was fup-
pofed by Lavoifier to be occafioned by the extrication of
phofphorifed hydrogen; but Davy accounts for it in a
different way. He afferts, this luminous appearance
arifes from the liberation of nitric phofacid, previoufly
formed during life, by the combination of light with
oxygen and nitrogen. He found by experiment that
putrefying fifh are equally luminous in water, when boiled
to expel the air and phofoxygen.

Hydrogen   6. *Hydrogen gas.* This is another production of pu-
gas.   trefaction. It was afcertained by Lavoifier from fome
experiments made on the fecal matter of a neceffary, that
the proportion of this gas increafes with the progrefs of
putrefaction, and he continued to obtain it for feveral
years after the fixed air had ceafed to be produced, al-

though Prieftley affirms the contrary. Lavoifier expofed
four inches of fecal matter to 24 inches of vital air under
mercury, and in ten days there only remained 22½ of the
air. This diminution of vital air, by it's expofure to
new fecal matter, he attributes to the effect of a fmall
quantity of inflammable air difengaged; for Prieftley has
obferved, that when inflammable air is difengaged flowly
from fermentefcible fubftances into vital air, there is an
infenfible union between thefe two airs at the moment of
the formation of inflammable air; and a further proof
of it's being this air which acts on the vital air at this
moment is, that if inftead of new fecal matter, which
affords very little inflammable air, old fecal matter, or
that which is a little advanced in putrefaction, be ufed,
it's action on the vital air is greater and more rapid, and
a much greater diminution takes place; at the fame time
the inflammable air, which would have been obtained by
the operation in veffels void of vital air, difappears:
hence it is probable that it effects by flow means what
takes place immediately in cafe of combuftion. (Vide
carbonic acid.)

Hydrogen gas has a very difgufting fmell, and it is
found to be capable of diffolving fulphur, phofphorus,
and even carbon, which fubftance it depofits again on the
addition of feveral chemical agents after the folution has
taken place. It is therefore afferted by feveral chemifts,
that the difagreeable naufeating and even infupportable
ftench which arifes from fubftances in a putrid ftate is
owing to hydrogen gas; either in it's free ftate, or holding
in folution fulphur, in which ftate it is called fulphurous
hydrogenous gas; or phofphorus, when it is called phof-
phorated hydrogenous gas; or carbon, forming carbonated
hydrogenous gas. The difference or degree of fmell may
likewife be attributed to the difference or degree of folu-
tion. If the hydrogenous gas be alone, it is perhaps the

leaft unpleafant; combined with fulphur, it has the fmell
of rotten eggs; and with phofphorus, that horrid ftench
is produced peculiar to ftinking fifh. The carbonated hy-
drogenous gas no doubt likewife produces it's peculiar
fmell, but as thefe odours are generally mixed during pu-
trefaction, they are perhaps only to be diftinguifhed at
particular ftages of it, when the one or the other predo-
minates.

Azot gas.   7. *Azot gas.* This is obtained from putrefying animal
fubftances either in it's combined ftate, or united with
hydrogen forming ammonia, or with oxygen forming the
nitrous acid; it may likewife form other combinations.
According to Fourcroy, this gas has a very peculiar and
diftinct odour refembling fifh juft beginning to putrefy;
it feparates a little carbon from animal fubftances, and it
gives the greenifh colour to parts, more particularly to
the mufcles, which is feen during their putrid ftate: this
chemift afferts it has a very deleterious effect on living
animals, and Dr. Mitchel of New York, as well as Drs.
Hamilton and Currie, are of opinion, that the gafeous
oxyd of nitrogen may have the principal fhare in gene-
rating contagious difeafes.

Pruffian   8. *Pruffian blue.* Fourcroy has found Pruffian blue in
blue.
animal fubftances during putrefaction, and a fmell of
pruffic acid has alfo been obferved; but as all animal
fubftances contain the principles of thefe two matters,
which require only an opportunity for a union, their
prefence in fome cafes is not furprifing.

Heat.   9. *Heat.* Whether this be a fubftance or a fenfation
produced by the repulfive motion of the putrid procefs,
it is found to take place in all matters undergoing that
operation, more particularly when in large quantities;
this is more evident in dunghills; and we are informed
by Munro, that upon thrufting his hand into the flefh of
a dead and corrupting whale, he felt a very fenfible heat.

10. *Earth.* When the volatile parts, or thofe capable Earth. of becoming fo, fly off or form combinations, and efcape in the order of their volatility, and the various odours they give rife to have vanifhed along with them, the putrefactive procefs is over, nature has performed her purpofe, her decompofition is complete, and there remains nothing but an infipid, blackifh, and carbonaceous fubftance, which is called the earth, a fpecies of caput mortuum, which has not been thoroughly examined. It is faid to confift of the oily matter of calcareous phofphat, and the phofphat of foda united to a portion of the carbonaceous principle.

From obferving the phenomena attending putrefaction Four ftages Boiffeau has diftinguifhed four ftages. The firft he calls of putrefaction. a tendency to putrefaction, which confifts of only a very inconfiderable change, perceptible by a flight faint fmell, and a foftening of the fubftance. The fecond degree he calls the commencement of putrefaction, this is fometimes indicated by marks of acidity, the fubftances lofe fomewhat of their weight, become foft and emit a fetid fmell; a ferous matter exudes from them if in clofe veffels, or they become dry or dark coloured if expofed to the air, although if the laft be moift there is little difference. The third degree he calls the advanced ftage of putrefaction, the fubftance emits a volatile alkaline fmell, mixed with a naufeous or putrid aroma, it diminifhes and falls into diffolution, the colour changes more and more, and it lofes both weight and bulk. The fourth degree, or complete putrefaction is known to have taken place by the volatile alkali being entirely and completely diffipated, the fetid fmell lofes it's force, the volume and weight of the fubftance are confiderably diminifhed, a gelatinous mucus is feparated, the mafs becomes by degrees dry, and is at length reduced to a friable and earthy matter.

Such are the general stages and effects which nature pro-
duces.

These phenomena are not however the same in all mat-
ters that undergo putrefaction. There is a great difference
between the putrefaction of the parts of living animals
and that of dead organs. Besides, every humour and
every solid part separated from a dead animal has likewise
it's peculiar manner of putrefying. The muscular, the
membranous, or the parenchymatous texture of the or-
gans; the oily, gelatinous, or albuminous nature of the
humours, their confiftence, their ftate with refpect to
that of the animal which afforded them, all have a more
or lefs great influence on the putrefactive procefs, and
modifying it in a variety of ways, perhaps impoffible to
be eftimated. If to thefe be added, the ftate of the air,
it's temperature, elafticity, weight, drynefs and moifture,
with many other circumftances, the actions of which are
more or lefs to be confidered, the phenomena will be ftill
more diverfified. Hence we may fay with Fourcroy, that
the hiftory of animal putrefaction is fcarcely begun, and
demands an immenfe feries of experiments and obfer-
vations.

Several caufes have been attributed to the production
of putrefaction. It was the opinion of fome philofo-
phers it was brought about by animalcula and infects;
amongft thefe were Linnæus, Kircher, and Plenciz; this
hypothefis, however, was overturned by the experiments
of Alexander. According to the opinion of Macbride,
fixed air is the fundamental caufe of putrefaction; for as
he fuppofes this to be the power of cohefion in bodies by
which their parts were kept together, it follows, that when
this is extricated, as is the cafe in all putrefaction, the
other component parts muft likewife fuffer a decompofi-
tion, the equilibrium between them being deftroyed.

Another opinion was, that phlogifton is the caufe of it, and as it was the fafhion to attribute almoft every chemical phenomenon to the abfence or prefence of this principle, it was confidently afferted, that the decompofition of bodies is brought about by this phlogiftic matter being extricated from them, or in other words, that the abfence of phlogifton was the production of putridity. The phlogifticarians, and particularly Ker, explain it in the following manner : they look upon the feparation of phlogifton from the other component parts of bodies to be the foundation of this procefs. When therefore putrefying fubftances are expofed according to circumftances that favour it, it begins firft by an expulfion of fixed air, by which much of the pure air of the organic matter is extricated to unite with the phlogifton for it's formation; another part of the phlogifton unites with the water, and, the volatility of both being affifted by the heat of putrefaction, rifes in the form of inflammable gas ; another portion of phlogifton evolved and freed from it's organic compofition unites with a portion of air, forming phlogifticated air; fome of this phlogifton uniting with a great deal of water, fome earth, and lefs air, forms volatile alkali ; the remaining phlogifton attracting flowly the pure air from the atmofphere, forms, with water and the fixed alkali or the pure earth of the organifed fubftance, a faline or calcareous nitre ; whilft the greateft part of the earth thus feparated from it's former combinations remains in it's proper form, or rather in a fomewhat phlogifticated ftate. It was then alleged, that the atmofpheric air was the grand caufe ; but according to Weber, this air is not only without effect, unlefs affifted by warmth and moifture, but from the experiments of Alexander, it's free admittance is not indifpenfibly neceffary to putrefaction. Fourcroy, and the French chemifts attribute it to the decompofition of water ; it is their opi-

nion this fluid is decompofed, that one of it's component
parts, the oxygen, feizes the azot of the animal fubftance,
and contributes to the formation of the nitrous acid,
and that the other component part, the hydrogen, unit-
ing with a portion of the fame azot which abounds, pro-
duces the volatile alkali.   The great difficulty, however,
refpecting the decompofition of the water is, that it is
unknown how it can take place at fo low a temperature ;
and to fhow that oxygen is always imbibed by putrefying
fubftances, it is only neceffary to examine the air, which
is found to be diminifhed, and the oxygen to have difap-
peared, whilft the prefence of the atmofpheric air is always
neceffary for putrefaction to take place, and the purer the
air, or the larger quantity of oxygen it contains, the
fooner and the more rapid is the putrefying procefs;
thefe are great proofs that this principle acts at leaft a
principal part in it's production ; but as before ob-
ferved, it is not the caufe of it.

Morveau, in order to find what action different forts of
airs would have upon animal fubftances, filled feven large
bottles, and fufpended in each an ounce of lean beef, he
then covered the bottle with a piece of bladder, and tied
it, leaving them for five years without being opened, when
he found, that

Grains.

In the vital air, the flefh was reduced to 136
          Common air 149
          Fixed air 157
          Inflammable air 163
          Nitrous gas...................... 155
          Ammoniacal gas 242
          Putrid gas 168

In the vital air, this chemift informs us, the putrid
odour was perceived the longeft time through the blad-
der, it was very ftrong after two months, whilft if that

in the common air be excepted, fcarcely any thing was
emitted from the others; hence it appears, that the vital
and common airs had a great advantage over the others,
which agrees with the nature of them determined by
other properties. All the pieces of flefh were found to
be dry and tending more or lefs to a black colour, efpeci-
ally that in the vital air, which fhows that it had made in
that air the greateft progrefs in putrefaction.

The caufe or origin of putrefaction is the refumption
of the chemical elective attractions which the compo-
nent remote parts of bodies had been deprived of by the
principle of life, and the confequent formation of new
combinations brought about by feveral acceffories, or as
they may be called, feptics, viz. *moiſlure, moderate tem-*
perature, repofe, and a communication with the external air.

A certain degree of moifture appears neceffary to give Acceffories
the component parts the liberty of coming within each or feptics.
other's attraction fo as to form new unions with the oxy-
gen of the atmofphere, and alfo amongft each other;
whereas drynefs prevents, or rather retards it, as well as
too much aqueous fluid; hence the preference of a moift
atmofphere.

2. A moderate temperature, fuch as 65°, is found to be
the heat of the atmofphere moft favourable to putre-
faction. On the contrary, a great degree is apt to vola-
tilize the parts of bodies before they can form a union,
and to produce exficcation; and a low degree, as that near
the freezing point, retards it by not giving the parts fuffi-
cient activity to form new combinations, whilft congela-
tion ftops it altogether.

3. Repofe is likewife a great affiftant in this procefs,
for without it there is no time for new unions to take
place, and a quick fucceffion of air takes away the moif-
ture fo neceffary, and dries the external parts; a confined
air is the greateft promoter of putrefaction.

4. Bodies will not putrefy in vacuo, hence the atmo-spheric air is equally neceſſary with the others, and it is always found to be diminiſhed, as is the caſe whenever it's oxygen is abſorbéd, *i. e.* in all proceſſes which the old chemiſts called phlogiſtic; and the larger the proportion of oxygen the quicker and more perfect is the putrefaction. It is on this account that great ſimilarity has been obſerved, particularly by Goddard, between the putrefactive proceſs and the action of fire on the atmoſphere during com-

Diſtillation buſtion, both converting ſubſtances into an earth, and compared to putrefac-tion. cauſing an abſorption of the oxygen of the atmoſphere, and a generation of fixed air; but as the putrefactive proceſs is much ſlower than either moiſt or dry diſtilla-tion, the products are different in ſome reſpects, from the great degree of heat not permitting the component parts to form the ſame unions. They both decompoſe animal ſubſtances and form new compounds. Both in diſtilla-tion and putrefaction, fixed air, ammonia, hydrogen gas, and ſulphureous hydrogen gas are obtained; but in the firſt, the heat being very powerful, forces more or leſs carbon from it's combination, which uniting with hydrogen forms an oil more or leſs empyreumatic, ac-cording to the quantity of carbon; whilſt in the ſecond, when there is ſufficient repoſe and time for the azot to unite with the oxygen of the atmoſphere, the nitric acid is produced.

Theſe four acceſſories being the grand promoters of pu-trefaction without which it cannot take place, it follows, that ſubſtances which are favourable to theſe promote pu-trefaction; and on the contrary, thoſe which impede them, more or leſs prevent it. It is principally on theſe grounds that experiments have been made to find what ſubſtances promote, and what retard or prevent it; the firſt have been called ſeptics, the other antiſeptics. For many experiments of this kind we are indebted to Prin-

3

gle, Macbride, Buckholz, Brugnatelli, Spielman, Mor-
veau, &c., but great additions are neceffary to determine
the relative powers of feptic or antifeptic bodies with any
degree of precifion.

Pringle and Macbride were the firft to make experi- Antifeptics.
ments to prove what thofe fubftances were that oppofed
putrefaction. In taking the general conclufions not only
of the experiments of thefe two phyficians, but of thofe
of Buckholz, Brugnatelli, and Morveau, it appears,
that fubftances which are antifeptic are not only incapa-
ble of putrefaction themfelves, but they deprive thofe
which promote it of their energy, at leaft in a greater or
lefs degree; among thefe are dry earths, acids, alkalis,
neutral falts, fpirituous liquors, effential and empyreuma-
tic oils, balfams, refins, fpices, bitters, aftringents, fmoke
of different kinds, and all gafes or airs, except thofe into
which oxygen enters as a conftituent part, as the atmo-
fpheric air.

All thefe impede the putrefactive procefs, at leaft, ani-
mal fubftances are longer in becoming putrid in them
than when expofed to the atmofpheric air, &c. It is likewife
found, that the fermentation of vegetable fubftances is
increafed by a mixture of animal matter, and the putref-
cency of the latter is corrected by the oppofite quality of
the former.

By making ufe of thofe means, which prevent putre- Preparation
faction, and by the affiftance of thofe fubftances that are of animals.
called antifeptics, the bodies of animals or their parts
may be preferved for a great length of time. This has
been practifed from the earlieft ages, by the name of em-
balming. According to Diodorus Siculus, the ancient
Egyptians were accuftomed not only to embalm the dead Art of em-
bodies of thofe animals their fuperftition had rendered ho- balming by
the Egyp-
ly, but likewife human bodies which were thus preferved tians.
from a fpontaneous decompofition, and are fo abundantly

to be found by the name of mummies. We are inform-
ed by Herodotus, as well as the before-mentioned author,
that the Egyptians had feveral methods of embalming
the human body, three of which are particularly noticed.
To this difference in the procefs, Leonhardi attributes
the different opinions phyficians and chemifts have had
of this ancient operation.

Three me-
thods.

1. A hole was made through the noftrils into the cra-
nium, the brain extracted, and the cranium was filled
with the embalming fubftance. The thorax and abdo-
men were then deprived of their vifcera, except the heart
and kidneys; they were wafhed with Phoenician wine, and
filled with fweet-fcented refins and aromatics; the opened
parts having been afterward fewed up, the body was well
wafhed and cleanfed, and placed in natron, which is fup-
pofed to have been the mineral alkali united with com-
mon falt, and found native in Egypt. In this alkali it
remained about 30 days; it was taken out and wafhed a
fecond time, befmeared over with a gum or refin, care-
fully enveloped with cotton bandages and placed in a cof-
fin. This method was very expenfive, but is the only
one that merits the name of embalming.

2. A cheaper way of preferving the body was to in-
troduce various refins, particularly that from the cedar,
by the anus, without opening either the belly or thorax,
the body was then dried in natron, and afterwards the
refin with the corroded inteftines were taken away.

3. The cheapeft method confifted merely in wafhing the
body, and it's expofure to the action of natron, which
we are informed deftroyed the flefh and only left the fkin
and bones.

Opinions on
the fub-
ftances em-
ployed.

With refpect to the embalming fubftance employed
on thefe occafions there are various opinions. Some, as
Rouelle and Vandermonde, look upon it to have been
afphaltum mixed with the oil of the cedar feed; whilft

Hardley thinks, with the ancients, it was the refin of this tree, or fome other vegetable refin. Belloni and Blumenbach are of opinion that afphaltum was ufed in common operations as being the cheapeft, and that, on particular occafions, the odoriferous vegetable refins were chofen; and the latter chemift, on the examination of ten different mummies, found no afphaltum, but very evident traces of vegetable refins. It is, however, certain that the fubftances for this purpofe were not always of the fame kind.

The art of embalming the human body has likewife been attempted by fome of the moderns, but the mere action of faline bodies, and filling the cavities of the body with aromatic herbs, were found not to be fufficient to preferve it from putrefaction. The beft and perhaps the only method worth attention is that pointed out by Dr. Hunter. As foon as the corpfe is become cold and ftiff, and before any fymptoms of putrefaction appear, it is to be well wafhed with warm water; one of the large arteries is then to be laid open, and the following injection to be forcibly made to enter the fmalleft veffels, even thofe of the cellular membrane. Two parts of the oil of chamomile are to be mixed with eight parts of oil of lavender, and fixteen of oil of rofemary; likewife the oil of turpentine may be either ufed alone or mixed with a little of the oils of rofemary and lavender; or, to give it a colour, a little cinnabar may be united with the oil of turpentine. The different vifcera are in a fhort time after to be extracted, the inteftines to be carefully cleanfed of their contents, and the reft of the vifcera to be deprived of their moifture by wiping them repeatedly with dry towels; the body is likewife internally to be cleanfed of it's blood and injected oils, by fqueezing the veffels; the arteries are then to be injected as well as the other large veffels that have been cut, with a mixture com-

Attempted by the moderns.

Dr. Hunter.

pofed of 6 lb. of oil of turpentine, 5 oz. of turpentine,
11 oz. of cinnabar, 2 oz. of camphor, and 3 lb. of
ftrong fpirit of wine; with this likewife the flefhy parts
that have been well deprived of any moifture are to be
carefully anointed, the veffels of the inteftines to be in-
jected, and then to be replaced in their former fituation,
fcattering a fufficient quantity of a powder about them,
compofed of 10 lb. of yellow refin or pitch, 6 lb. of
faltpetre, and 5 oz. of pulverized camphor, fo that every
vacancy may be perfectly replete with it. Afterward,
when a little of the injecting liquor above mentioned
has been poured into the thorax and belly, the fkin is to
be clofed, the mouth, pharynx, and larynx fyringed and
filled with the powder, together with the cavities of the
ears, nofe, anus, parts of generation, eyes and eyelids,
and the whole body, after having been previoufly wafhed
and rubbed dry, is to be well rubbed with alcohol and
camphor, and finally with the oils of rofemary and laven-
der. The body being thus embalmed, in order to deprive
it of any remaining moifture, it is to be laid in a coffin
upon fome calcined and finely pulverized gypfum, fo as
to be on all fides about half covered with it; pieces of
camphor are to be ftrewed about, and a range of open
bottles filled with volatile oils; the coffin is then to be
well clofed, having a lid with a glafs in it. In about four
years the gypfum fhould be renewed, and when the body
is perfectly dry, it may be difpenfed with altogether.

Preparation
of animals
by natu-
ralifts.

Befides the embalming of the human body, chemiftry
is able to afford great affiftance to the naturalift in the
preparation of quadrupeds, birds, and other animals that
compofe collections of natural hiftory. It affords the
moft proper means not only of being able to give them
duration and confiftence, but to make them deviate, as
little as poffible from the living ftate, that by their atti-
tudes and moft natural pofitions, they may be enabled to

exhibit in great perfection both their inftinct and cha-
racter, circumftances of great importance in the fcience
of natural hiftory.

For thefe effects, the methods publifhed by Reaumur
in the 45th vol. of the Philofoph. Trans., and thofe rela-
ted in the Dict. d'Hiftoire Naturelle, when chemically
examined, are far from being fatisfactory. Independent
of the method of embalming propofed by Dr. Hunter
juft mentioned, which may be applied alfo to fubjects
deftined for natural collections, feveral chemifts have
given directions for that preparation ; amongft the prin-
cipal of which are Kuckham, Chaptal, and Pinel.

Kuckham publifhed a procefs for the preparation of birds Method of
in the 60th vol. of the Philofoph. Trans. His compofition Kuckham,
to preferve them from putrefaction is a mixture compofed
of a quarter a pound of corros. fub.; half a pound of cal-
cined faltpetre; a quarter of a pound of calcined alum ; half
a pound of flowers of fulphur; a quarter of a pound of mufk;
one pound of black pepper, and one pound of pulverized
tobacco ; thefe are to be kept in a well-clofed glafs veffel,
and in a dry place. The corrofive fublimate is very fatal
to infects ; and, according to Pinel, the only objection to Pinel.
the mixture is the expenfe. He therefore fubftitutes the
following in it's place ; equal parts of corros. fubl. or
arfenic, calcined alum, camphor, canella, or any other
aromatic, are to be pulverized and mixed together. Pinel
has likewife made ufe of a varnifh with great fuccefs ; it
was, he informs us, at firft kept a fecret, and is a very
fure means to prevent the generation of infects in the
fkins of dead animals, or to deftroy them when hatched ;
fo that for three or four years, until they can be conve-
niently placed in the collection they are deftined for, the
keeping them under cafes of glafs may be difpenfed with.
It is compofed of the following articles : Four ounces of
pulverized arfenic are to be put into one pound of brandy,

the mixture heated gently, fome black foap and aloes are then to be added, fo as to form a kind of magma, which muft be lightly extended whilft warm in the interior of the animal with a brufh, the foft parts having been taken away; the fame procefs muft be applied to the internal furface of the fkin. When ufed, he recommends it to be diluted with alcohol. Immediately after it's ufe, the preparation fhould be *mounted*, as the evaporation of the fluid part occafions the fkin to become hard and diffi-cult to foften again.

It is with this magma that cotton or flax ought to be impregnated, with which the internal parts of animal bodies are to be filled, and it is found to be far fuperior to the mixture compofed of a folution of camphor in rec-tified fpirit of wine, which is commonly ufed in this country. It is likewife neceffary that the zoologift fhould be provided with cauftic foda, a folution of which cor-rodes the foft parts, and by uniting with the fat parts forms a fpecies of foap that is afterwards eafily taken out by repeated lotions. Chaptal recommends the cranium and inteftines, when deprived of their contents, to be fyringed with vitriolic ether.

Chaptal.

Small animals, or the parts of large ones, are ufually preferved by being kept in fpirit of wine; for this purpofe, it is obferved by Leonhardi, that a little water and a fifth part of fpirit of fal ammoniac fhould be added, which will preferve the colour and foftnefs.

A method of preferving anatomical fubjects in a very perfect manner, is the following. It is faid to have been made ufe of by John Sheldon. He injects feveral parts of the body with ftrong fpirit of wine, faturated with cam-phor, and mixed with a fmall portion of turpentine. The fkin is prepared with finely pulverized alum, rubbed on with the hand. The inteftines are taken out and covered with a varnifh, compofed of a mixture of camphor, and

Sheldon.

common refin. All the internal parts of the body un-
dergo the fame operation, and are afterwards rubbed with
alum. The body thus prepared is laid on a bed of cal-
cined chalk to the thicknefs of one inch, in order to ab-
forb all humidity, and is then placed in a double cafe of
wood, the inner of which is of cedar. In this manner
he has been able to preferve the body of a young woman
for feveral years, which retains it's form and appearance
nearly as perfect as in life. Even the natural tint of the
fkin of the face is preferved, by a coloured injection im-
pelled through the carotids to produce that effect.

Chauffier has difcovered, that if the bodies of men or Chauffier.
other animals be plunged for fome time in a folution of
corrofive fublimate, and then dried, they affume the
confiftency of wood, and the air produces no effect
upon them afterward; and if the bodies be injected pre-
vioufly, they will retain the colour and appearances of
life, and confequently form mummies more perfect than
the Ægyptian.

It is well known, how difagreeable and very incon- Fourcroy.
venient that putridity is to the anatomift, which often fo
foon takes place in bodies or their parts under diffection,
and to Fourcroy it is, that we are indebted for a method
by which thefe inconveniences may be prevented: it con-
fifts in fprinkling the parts with oxygenated muriatic acid.
He informs us, the abdominal mufcles of a fubject for
demonftration having been removed, and the cavity of
the abdomen laid open, notwithftanding the contents
were carefully removed, it was found to exhale a confide-
rable putrefactive fmell; care, however, being taken to
wafh the whole internal furface with the liquid oxygena-
ted muriatic acid, the odour was immediately deftroyed,
and the ftudents that had quitted the body foon refumed
their fituation without being afterwards incommoded;
they alfo continued their diffection in the abdominal

R 4

cavity, and in the cheft, which was alfo wafhed with the fame, for a much longer time than ufual without perceiving any degree of fetor. A mild and humid ftate of the air, during which the putrefaction of bodies is known to proceed very rapidly, produced little effect for the fpace of eight days, on the body fprinkled by the acid, whilft in the fame period other bodies had acquired the higheft degree of putrefaction. The mufcles, the nerves, the vafcular membranes, and all the other parts continued firm and without alteration.

This chemift therefore advifes, that in bodies for diffection, the parts fhould be fprinkled as they are laid open. This method, which will preferve bodies for more than fix weeks, taking care to repeat it from time to time, is eafily practifed, as a fponge dipped in the acid is flightly rubbed over the parts, taking care to avoid the vapour by turning the head afide.

He likewife advifes the ufe of this acid for another purpofe during diffection. One of the great difficulties in diffecting the foft and pulpy parts, as the brain, cerebellum, medulla oblongata, and fpinal marrow, is the want of firmnefs in their ftructure, and the confequent yielding of their particles to any impreffion. This foftnefs likewife renders them very liable to change by putrid decompofition, and they become oftentimes fo putrid in a few hours, as to make it impoffible to determine their ftructure, although thefe parts, to be well underftood, require a long and attentive examination. It has been propofed to heat them a little above 45° of Reaumur, to give them a firmer confiftence, and although the albuminous matter which forms their bafis is fufceptible of this denfity from the impreffion of heat, it is not fufficient for the anatomift, as the foft fibres of thefe organs are compreffed together, and become lefs apparent after the operation. Fourcroy, therefore, thinks he has dif-

covered a more advantageous method. Having ob-
ferved that all animal fubftances, efpecially the fkin,
membranes, &c. become firm and compact after mace-
ration for fome hours in liquid oxygenated muriatic acid,
and that their fibres were made to approach each other
in a remarkable manner ; he fteeped a human brain for
eight hours in this liquid, and afterward plunged it once
or twice in frefh water to wafh off the acid, and found it's
fubftance became firm, was readily cut, and it's tiffue
not diforganized by gentle preffure, as is generally the
cafe with this organ. It alfo preferved it's whitenefs and
confiftence for more than eight days, and did not become
putrid in near the fame time as in ordinary circum-
ftances.

The utility of this property of the acid, in hardening
and preferving animal fubftances, is likewife extended to
the foft and almoft mucous flefh of moft fifhes, and the
glairy fubftance of worms, fnails, &c., which is of great
importance in the art of anatomy.

Having defcribed the phenomena, and the circum-
ftances attending *atmofpheric* putrefaction, and the me-
thods of preferving animal fubftances from it, an account
of the decompofition they undergo, on expofure to other
mediums, may be a means of throwing fome light on
the revolution the animal creation goes through in it's
various metamorphofes.

2. *Terraneous putrefaction.*

The phenomena which take place when bodies are
buried in the ground are different from thofe which fol-
low on expofure to the air. It appears their deftruction
varies according to the nature of the foil. Sometimes bo-
dies are found to have undergone a total decompofition
after a very fhort interval, and at other times, as is the
cafe with mummies, centuries are neceffary entirely to
deftroy them. It is eafy to conceive, according to Four-

2. Terra-
neous pu-
trefaction.

croy, that if the earth be very porous and movable, if the animal matter be buried at a fmall depth, the air, and efpecially the water, which can have no difficult accefs to it, will facilitate it's decompofition, whilft in oppofite circumftances it muft be much flower ; thus, for example, if the earth be dry, it will abforb the aqueous part of the bodies, exficcate and convert them into mummies, as is the cafe in Egypt, where a fandy foil expofed to a burning fun gives them a hardnefs that defends them from deftruction for ages. On the contrary, if the bodies be buried in argillaceous earth, which retains the water, the deftruction is accelerated. In thofe cafes where the decompofition takes place more or lefs flowly, the fluids and the folids become at laft reduced almoft to azot, carbonic acid, hydrogen, and alkaline gafes. All thefe elaftic fluids being filtered through the earth, efcape and experience other viciffitudes; but as the fpontaneous decompofition of animal matters, efpecially when buried in large maffes in the earth, affords fome curious and fingular refults, it will be neceffary to give a more detailed account of them, fuch as they have been collected by Fourcroy, in a memoir written on the bodies found in the churchyard of the Innocents at Paris.

Bodies in the Innocents at Paris.

It appears that the earth of this churchyard had been furcharged for many ages with bodies delivered up to putrefaction in large maffes, which in confequence might be fuppofed to have a different effect from that of other cemeteries, where each body has it's peculiar lot of ground, and where nature is able to feparate it's elements with facility and promptitude. The calculations of fome philofophers had indeed extended the total deftruction of a body to about fix years, from the obfervations made upon common burying places; but thefe could not be applicable to the cemetery of a large city like Paris, in which many fucceffive generations of it's inhabitants had

been buried for more than three ages ; for nothing indicated that the entire decompofition of a body might be prolonged beyond forty years, nor could it be fufpected what a fingular difference nature was able to prefent in the deftruction of bodies buried in large quantity, and of thofe only ifolated in the earth ; nor could it be known what might be the effects of an earth many yards deep, the ftratum of which was inceffantly expofed to putrid emanations, and faturated with animal effluvia, upon new bodies placed in it ; thefe, however, have been difcovered by Fourcroy, forming an important addition to the hiftory of animal decompofition or putrefaction.

The remains of the bodies buried in this churchyard *Found in three different ftates.* were found in three different ftates, which appeared to depend on the time they had been inhumed, the places they occupied, and their difpofition relatively to each other.

1. The oldeft only offered to obfervation a few portions of fcattered bones placed irregularly in the foil from having been often difturbed to give place to others, and in which nothing appeared except their difference from other human bones that had not been in the earth, and it was with refpect to the foft parts including the teguments that the two following differences were obfervable.

2. Of the ifolated bodies, the fkin, mufcles, tendons, and the aponeurofis, were dried, brittle, hard, of a more or lefs gray colour, and refembled the mummies in the catacombs at Rome, or in the cellar of the Cordeliers at Touloufe.

3. The third, and moft curious ftate, was found to exift in the foft parts of the bodies that were accumulated in the common pits. Thefe pits were above thirty feet in depth, twenty broad, and of the fame width ; they were dug in the cemetery for the reception of the bodies of the poor, which were placed in clofe ranks, in coffins,

fo that the whole pit was a mafs of bodies feparated only
by the thin fides of the coffin, and each pit contained
from 1000 to 1500 bodies. Three years were neceffary
to fill one of them, and they were opened again to re-
ceive other bodies not fooner than fifteen years, nor later
than thirty years. The gravediggers had, however,
been taught by experience, that this period was infufficient
for the total decompofition of the body, whilft the alte-
ration it underwent during the time was well known to
them. This change likewife ftruck the obfervation of
Fourcroy, in the very firft pit he was prefent at when
opened. It had been filled and clofed about fifteen years.
The fides of the coffins were found, and tinged of a yellow
colour. On taking off the lids, the bodies appeared flat
as if they had been preffed, and when the fhrowd was
removed, the matter that furrounded the bones was in
irregular maffes of a foft ductile confiftence, and grayifh
colour. On preffing this matter with the finger, it gave
way and broke. It refembled in appearance common
white cheefe, and the print of the linen left upon it's
furface heightened the refemblance. On rubbing this
fubftance, it became foft. The gravediggers were accuf-
Their curi- tomed to call it *fat*, from it's great fimilarity to that fub-
ous conver- ftance, but they only found it in bodies buried in mafs,
fion into a
fat matter. and never in the ifolated ones. There was no infectious
or very difagreeable odour perceived. This chemift exa-
mined many bodies of this kind, but all were not equally
far advanced in this fingular converfion, fome of them
had ftill portions of mufcles remaining amongft thefe
white fat maffes, which were recognized by their more
or lefs red colour and fibrous texture. In the bodies to-
tally converted, there was no veftige of either fkin, mem-
brane, mufcle, tendon, veffel, or nerve; the grayifh
white mafs that covered all the bones appearing like cel-
lular membrane, which, according to this chemift, might

induce an opinion of the mucous part being the real bafis of this fingular matter. On examining further, it was found that all the vifcera were likewife fo changed as to leave fcarcely any trace of them ; the abdominal cavity no longer exifted, and it was in vain to feek in the greater number of bodies either for the fituation or fubftance of the ftomach, inteftines, bladder, liver, kidneys, or womb; all were, to ufe the expreffion, melted down into this fatty matter. It was the fame with the cavity of the tho-rax, it no longer exifted. It's vifcera were often entirely changed, and the greater part had difapppeared, nothing remaining but fome lumps of this white fat. He found this matter, which is the product of the decompofition of the vifcera charged with blood and different humours, to differ from that on the external part of the body and bones, by being always of a more or lefs red or brown colour, and that the fat parts afford a much greater quan-tity than the others.

The face, in general, was no longer to be recognized; the mouth was diforganized, and without tongue or pa-late ; the cartilages even of the nofe partook likewife of the general alteration ; the orbits, the ears, were equally changed. The fkin, however, retained the hair, which appears to fubfift the longeft, and make the greateft re-fiftence to every change, whilft the brain was always prefent, but converted like the other organs.

With refpect to the modifications of this fubftance, it's confiftence was not always the fame ; in bodies the lateft changed, *i. e* from three to five years, it was foft and very ductile; very light, and contained a large por-tion of water ; in thofe which had been changed from thirty to forty years, it was more dry and brittle, it's foliated texture was much denfer ; and in fome bodies where the foil was dry, portions of it were become femi-

tranfparent, and it's afpect, texture, and brittlenefs, very
well imitated wax.

The epoch of it's formation has likewife a great influ-
ence on the nature of this fubftance; all that had been
formed a long time was in general white, homogeneous,
without any appearance of fibrous or foreign matter, and
this was more particularly the cafe with the fkin of the
extremities. On the contrary, in bodies recently con-
verted, it was not fo pure; there were fome portions of
the mufcular, tendinous, or ligamentous parts, the tex-
ture of which, though they were altered in colour, was
ftill to be recognized; but thefe were more or lefs pene-
trated with fat matter, to be feen between the interftices
of the fibres. Hence not only the fat parts, but the
other parts are really converted into the fame fubftance,
although the firft undergo the change much more eafily
and quickly.

From the obfervations of Fourcroy, it appears, there-
fore, that amongft the modifications refpecting the ftate
of bodies converted into fat, two varieties may be diftin-
guifhed; the one dry, friable, and brittle; the other
foft, and ductile; to which may be added, that the firft,
which is oftener found in bodies placed near the furface,
not only differed from the other by the water it had loft,
but it had undergone a new change, and it had loft one
of it's principles by volatility, fo as no longer to be of the
fame nature as the other, as will appear.

Two varie-
ties of it.

This fat matter, in fome of the bodies, was very beau-
tiful, it's furface brilliant, and of the colour of gold and
filver, and appeared covered over with a flight ftratum of
mica, whilft fome points were of a red, orange, and car-
nation colour, and of extreme brilliancy, more particu-
larly near the bones, which were themfelves penetrated
with it.

From the account of the fexton, it feems nearly three years are neceffary for a body to become changed in the earth, and the fucceffive alterations they undergo before they arrive at the ftate already mentioned, are the follow- ing: the inhumed bodies appear not to be fenfibly changed in colour before feven or eight days, and this al teration firft takes place in the lower belly, as is the cafe with thofe bodies not inhumed. The belly fwells, and appears to be diftended by the elaftic fluids difengaged from the incipient decompofition, and this follows more or lefs early, according as the belly is more or lefs large and filled with fluids, the depth it is buried, and more particularly, according to the more or lefs warm tempe rature of the air. Hence, if all the circumftances fa vourable to this firft degree of putrid decompofition be united, a very fat body, the abdomen of which is expof ed to moifture by being buried near the furface, and the feafon warm, will become fwelled in three or four days, whilft a meagre body, deeply inhumed, and in a cold feafon, will remain feveral weeks unchanged. It is a fact worthy of obfervation, that the ftate of the atmofphere during a ftorm has great influence in producing this fwel ling, and the expreffion of the gravedigger is that the belly *bloats* at the approach of ftorms; this diftention in creafes until the parts are fo extended and relaxed by pu trefaction, as to burft with a fort of explofion, which happens near the umbilicus, and fometimes around the navel; from this wound runs a fanious, brownifh fluid, of a very fetid odour, and at the fame time a very me phitic elaftic fluid is difengaged, the dangerous effects of which the gravediggers have learned to dread from ex perience. Multiplied experience likewife, which tradition has confirmed, has inftructed them, that it is only at this period the miafmata difengaged from putrid bodies have any effect, from which real danger is to be expected. We are informed by this able chemift, that fo ftrong is this

gas, that it feveral times happened when the pickaxe has accidentally ftruck upon the lower belly, an elaftic fluid efcaped, from which the perfon employed was fuddenly ftruck down in afphixy, and hence arifes the dangers of the fexton; but for a further account of this miafma, vide article *Miafmata*.

The diftention and rupture of the lower belly equally takes place in bodies heaped together as in the pits, and thofe that are ifolated; but the changes which fucceed this firft period of fpontaneous decompofition are, as has been already mentioned, very different in each.

The ifolated bodies being furrounded with a large quantity of moift earth are entirely deftroyed, and prevented therefore from undergoing all the fucceffive degrees of common putrefaction; this deftruction is the more quick, the more humid the body is, and according as the heat or coldnefs of the feafon is accompanied with humidity. If, on the other hand, the ifolated bodies are dry, or emaciated; if the earth in which they are placed is acid and void of humidity; if the atmofphere is dry, or if the rays of the fun falling on the furface favours and accelerates the evaporation; all thefe circumftances united exficcate the bodies by abforbing or volatilizing the aqueous parts, and by contracting the folids, fo as to give rife to thofe fpecies of mummies before mentioned.

In the pits, every thing is different, the great mafs of bodies heaped upon each other, and at a great depth, are not as the ifolated ones are, expofed to the influence of external agents, or if at all, in a very inferiour degree; hence the changes they are fubject to depend on their own fubftance.

When the rupture of the lower belly has taken place, the abdominal putrefaction that caufed it appears to have already diforganized the vifcera of this cavity, the ftomach and inteftines no longer form a continued mem-

branous tube. Broken in many parts, and already dif-
folved into a putrid fanies, this procefs becomes more ra-
pid and totally deftroys the texture; the parenchyma of
the liver, however, from it's folidity perhaps, feems to re-
fift this feptic menftruum, the putrefaction does not ad-
vance to a complete deftruction from the deficiency of
humidity, and fuch undoubtedly is the caufe of thofe
fragments of fat that are found inftead of all the abdo-
minal vifcera.

The putrefaction excited in the abdomen foon commu-
nicates with the thorax by diffolving the fibres of the
diaphragm; hence the more or lefs complete deftruction
of the veffels, membranes, and all the foft parts of this
cavity, every thing announcing that it's diforganization
goes on at the fame time as the abdomen's, or at leaft very
foon after; hence in this part only a few irregular maffes
of fat remain. The fame diforganization takes place
with more or lefs energy in all the mufcular, tendinous,
and ligamentous parts that furround the bones, according
to their foftnefs and the quantity of their aqueous parts;
the converfion into this fat fubftance fucceffively pervades
every part; every thing that is membranous and more
or lefs mucous is deftroyed and difappears, and there
is no longer any trace of veffels, nerves, or aponeu-
rofis in thofe maffes of fat that cover the bones of the
extremities; all are converted into this fubftance.

Fourcroy, on examining, the other cemeteries, found
that the fame alteration took place in the inhumed bodies
as in that of the Innocents; hence the formation of this
curious fubftance does not belong exclufively to the foil,
but takes place perhaps univerfally where bodies are buried
in large maffes by the fide of each other, and where, be-
ing lefs expofed to the action of thofe agents that operate
in common external putrefaction, are only expofed to the
reaction of their own component parts on each other.

To this may be added, that this chemift likewife found, on vifiting a great number of burial places in Paris, that the change of bodies into mummies by exficcation was much more common in a great number of foils than is generally fuppofed.

The conversion into fat arrefts the putrefactive procefs.

The bodies converted into this fubftance in thofe pits that have been filled up for 40 years, prove, that once arrived at that ftate they are capable of being preferved a long time without being fubject to intire deftruction, whilft nature at the fame time, who fpares nothing, muft certainly be in poffeffion of fome means of decompofing this new fubftance, and of reducing it again to it's elements. What became of it when formed, this celebrated chemift was defirous of finding out, but the moft experienced and oldeft grave diggers were not able to afford him the leaft fatisfaction on this interefting point. Some facts however, appear to authorize a belief of his having difcovered one of the proceffes by which it is detached from the bones, and decompofed.

It's final decompofition.

In fome of the coffins that had been deranged from their horizontal to an oblique pofition from part of the earth having given way, the inferiour portion of the body was found reduced to the ftate of a fkeleton, whilft the fuperiour part ftill preferved it's maffes of fat : hence a menftrual caufe was looked for that had acted on the lower without touching the upper part.

On examination, this chemift found in the inferiour part of the coffins a brown and fœtid fluid, the earth about them was likewife moift and penetrated with the fame matter as the water in the coffins ; thefe were only to be found, however, at the bottom of the pits, and in general the fat of all the bodies that occupied this region was the fofteft, the moft changed, and the leaft in quantity. Thefe phenomena indicated to him the action of rain water which had filtered itfelf through the earth,

was collected at the bottom of the pits, where it bathed
that part of the bodies within it's reach, and was im-
bibed by the fat matter. This account was corroborated
by the gravediggers, who obferved, that after long and
heavy rains the foil at the top of the pits is apt to fink
for fome inches. This proves the reafon of the diminution
in the mafs of bodies, the fat or foluble part of which is by
degrees taken up by the water, and diftributed in more
minute particles to the furrounding earth, and in which
this chemift found the elements of this peculiar fub-
ftance. Such is the progreffive fucceffion of the natural
phenomena obferved by Fourcroy in the changes bodies
undergo in the earth; but he very properly adds, it is
only an imperfect fketch of a great picture, to which fu-
ture chemifts muft add the finifhing touches.

To render it more perfect, and to know and defcribe,
in all it's ftages, the flow and gradual decompofition of
dead bodies inhumed in the bofom of the earth, is a la-
mentable tafk; it is to be indefatigable for an age in the
moft forrowful inveftigations, and to live amongft tombs,
and breathe the noifome effluvia arifing from them.

From the experiments which Fourcroy made on this Experi-
ments and
fat matter, it appears that it is an ammoniacal foap formed obfervations
of a *peculiar concrefcible oil,* united in different proportions on the fat.
with ammonia; and that this foap likewife contains fmall
quantities of the phofphats of ammonia and lime, which,
however, do not enter the faponaceous combination, but
are only interpofed between it's particles; their quantity
likewife varies in a fingular manner.

With refpect to the proportion of ammonia, it is al-
moft impoffible to afcertain how much the fat contains.
It's proportion varies according to the time it has been
taken out of the earth, as was proved by it's flow de-
compofition when expofed to the air, for the ammonia
not being very adherent, an external heat above 15° is

fufficient in time to effect it's feparation; the proportion
likewife probably varies at the period of it's formation in
each body, which depends in particular on the nature of
the body itfelf. This matter therefore is not to be re-
garded as always identic, and as containing the fame
principles in the fame proportion. The ftate of each
body, the epoch of it's burial, the fituation, the height
it occupies in the pit, the number of bodies, the difpo-
fition, the greater or lefs quantity of them, muft have
great effect on the difference in the quantities of the com-
ponent parts of this foap. Likewife when it is expofed to
the air on being taken from the pits, the proportion of
it's principles will vary according to the place it is expofed
in, the fize of the pieces, and the temperature and dry-
nefs of the air. But the moft effential point to know, is,
that this foap continually tends to decompofition, that
the ammonia is by degrees difengaged, and that at laft
the febaceous matter which makes the bafis of it is left
intirely naked and in the form of a yellowifh oily concre-
tion, femitranfparent, dry, brittle, and granular in it's
fracture.

This fat is diffolved neither by cold nor boiling water,
but it abforbs it with fuch activity, and adheres to it in
fuch a manner, that it retains a great quantity which fin-
gularly augments it's volume. This adherence renders
the water thick and vifcous, and prevents it from paffing
through the pores of the filtering paper. On the addi-
tion of fulphuric acid, Fourcroy found, that a gas, or
rather an odorous effluvium was extricated, of an infupport-
able fœtidity; it was very fixed, and infected the labora-
tory for feveral days afterwards, although the windows
were often kept open. This gas, therefore, is very diffe-
rent from that of common fat. By the nitric acid azot
gas was only extricated, when the fat contained the re-
mains of fibres; when pure it affords carbonic acid gas.

This oil, or concrete oily matter, appears to be different *Is a new* from all others hitherto difcovered, and is a new product *production.* arifing from the decompofition of bodies under certain circumftances, which had efcaped the attention of chemifts. For a particular account of it *vide animal oils.*

A fimilar decompofition appears to have taken place in *A fimilar* a liver, which although it had been expofed to the exter- *in a human* nal air, feems, by having become exficcated, to have ef- *liver.* caped the total decompofition which is the confequence of fuch expofure. In the beginning of the year 1785 a piece of human liver was examined by Fourcroy, which he received from Poulletier de la Salle; this liver had been expofed for more than ten years to the open air fuf- pended by a packthread ftring. It had at firft given out a difagreeable putrid odour, had been in part deftroyed by the larvæ of feveral infects, but without being totally dif- folved by putrefaction, was become reduced by degrees to a gray friable matter, and for three or four years appeared not to have undergone any new alteration. From the firft afpect of this piece of liver it might have been mif- taken for an earthy fubftance, analogous to that called mineral agaric; on a clofer examination however, fome portions of dried membranes of a brown colour were very evident, together with fome vafcular parts equally dried. When rubbed between the fingers it was greafy and foft to the touch, refembling foap. From the experiments this chemift made upon it, although he was limited as to the quantity, it appears to be analogous to what he found in the remains of the bodies above mentioned, inhumed in the cemetery at Paris, or in other words, that it was a concrete oil refembling fpermaceti.

1ft. A fmall portion of it placed on a hot coal at firft became foft, and exhaled an odour fimilar to burnt fat; it then melted, fwelled, and became black; on incinera-

tion, the light carbonaceous matter was converted into a
white ash.

2d. On distillation, half an ounce afforded a few drops
of a white aqueous insipid fluid, which was soon suc-
ceeded by a thicker fluid, and an oily white smoke, which
was condensed in the neck of the retort into a white con-
crete matter; afterwards a very putrid disagreeable odour
was perceived, the concrete oil became of a rust colour;
carbonated hydrogenous gas was obtained. A great
part of the liver had passed without decomposition. The
concrete oil in the neck of the retort had a lamellated and
crystalline appearance. The products showed no signs of
either an acid or an alkali.

3d. Two ounces of hot water dissolved a little out of
one drachm. The solution was white and opake, had a
slight soapy odour, and sensibly changed the syrup of vi-
olets green; the undissolved portion melted by heat,
crystallized on cooling, had a fat odour, and inflamed;
this slight solubility showed it consisted of an oily con-
crescible matter.

4th. A drachm of it triturated with half an ounce of
the caustic lye of potash produced a slight odour of am-
monia; boiled for half an hour and filtered, the solution,
on cooling, became concrete, of a brown colour, and dis-
solved in every proportion in boiling distilled water, leav-
ing no residuum. It appeared that the whole of the liver
had been dissolved by the alkali, even it's membranous
and fibrous parts. This solution in water frothed very
strongly on agitation, and on cooling deposited some white
light flakes. Limewater, acid, and earthy neutral salts
precipitated them more abundantly. Hence the alkali
had dissolved a fat oily matter, and formed with it an ho-
mogeneous soap.

5th. Two ounces of alcohol with one drachm of the

levigated liver expofed to a gentle heat diffolved about half of it, and the refiduum treated twice more with alcohol, there only remained 20 grains undiffolved, formed of membranes and veffels that had efcaped the action of the alcohol. On the addition of water, a fubftance was precipitated in the form of white flakes, which was a concrete oil refembling fpermaceti, for which *vide animal oils*.

6th. The oil expreffed from the liver after expofure to a heat of 68° of Reaumur, in water, and rendered concrete by cold, had nearly all the properties of that diffolved in alcohol, except, firft, it had more colour, and was more fetid. Second, it contained a portion of foap, which the water had feparated from the alcoholic folution in the firft inftance.

7th. The portion of foapy matter regarded as an extract in the firft experiment, excited the attention of this chemift. It was certain that water as well as alcohol extracted it from the dried liver; but there was too little of the liver left to make any experiments upon to find out the nature of this foap. It appeared to be formed of the fame concrefcible oil as that extracted by expreffion, &c. It was even conjectured by this chemift, that before the complete alteration of the liver, and it's total converfion into a concrete oily fubftance, this oil was at firft in a foapy ftate intirely united to foda and ammonia, fince it appeared that the portion of ammoniacal foap ftill remaining in this piece of liver proved, by the ammoniacal odour difengaged by quicklime, and it's infolubility in water, to be more abundant in that portion of the liver that was deeper and lefs expofed to the air than that examined. Such are the experiments he made on this fubftance.

Hence it appears, that this concrete oily matter found in the bodies in the churchyard at Paris, and in the hu-

man liver, is the conſtant product of a ſlow decompoſi-
tion, of a long putrefaction.

Another inſtance of a ſimilar converſion, and in conſe-
quence the long preſervation of a certain organ of the
body, is the brain. The propenſity of the brain to cor-
rupt before moſt other parts of the body is well known
to diſſectors, and yet under certain circumſtances, it is
the laſt viſcus deſtroyed by putrefaction ; and this ſingu-
lar faculty of reſiſting deſtruction has been long ago ob-
ſerved. Fabricius de Hilden relates, after George Faber,
an example of this kind ; the body had been buried 50
years, but the brain, he informs us, had undergone no
ſenſible alteration ; it was white, ran like an oily matter,
yet exhaled no noiſome ſmell. According to Theo-
philus Raynaud, a brain was found at Avignon equally
ſoft and of the ſame nature, whilſt the body had been
buried a great number of years. Peter Borell gives an
account of the brains of ſome maſſacred people, whoſe
bodies had been thrown into the wells of the Domini-
cans, at Ceſtres, that after 80 years were ſtill ſoft and
without ſtench. A memorable example of the ſame
kind was found in the celebrated catacombs of Kiovie,
on the banks of the Boriſthenes, a deſcription of which
we owe to Herbinius. This author aſſerts, that the
crania of a great number of mummies perfectly preſerved
in thoſe places, are filled with a fat and oily matter that
runs from them. The reſemblance of this oily matter
with that already mentioned by Fourcroy, is a proof of
the obſervation having been made before, although no
experiments had been made upon it.

3. *Aqueous putrefaction.* It alſo appears, that all ani-
mal ſubſtances, except the bones, nails, and hair, are
equally ſuſceptible of being converted into this fatty
matter on being expoſed to the effects of water.
Rouelle and d'Arcet, in 1777, had obſerved a phenome-

non of this kind in a dog, found under water in the Converfion of a dog. Seine, all the flesh of which was converted into this sub-ftance. This fact has been fince confirmed by the expe-riments of Gibbs; for having placed at different times a couple of cows and two horfes in water, or in a running stream, the flesh was converted into a fubftance refem-bling fpermaceti. The cow was placed in a fituation where the water could have accefs twice a day; over it fome loofe earth was thrown: after it had remained fome time, on pufhing a ftick through the earth to the body, a prodigious quantity of extremely offenfive air arofe, and in one year and a half the whole mufcular part was changed into this white concrete matter. The water over the animals, and for fome diftance around them, is covered with a beautiful pellicle, which is white in gene-ral; fometimes it refracts the fun's rays, producing the prifmatic colours. He likewife expofed a piece of beef in a box pierced with holes to the current, and found it had undergone a fimilar transformation in one month after.

Cow.

Horfe.

Fifh may alfo be changed, and it appears this concrete matter is formed in the body of an animal. Gibbs ob-ferved, on feeing a body opened where there was a great collection of water in the cavity of the thorax, that the furface of the lungs was covered with a whitifh cruft, which he attributes to fome combination that had taken place between the lungs or pleura and the ferous fluid effufed, fimilar to that between flefh and water. Dr. Cleghorn alfo mentions a fimilar circumftance, in fpeak-ing of abfceffes formed in the lungs. Thefe abfceffes had fometimes emptied themfelves into the cavity of the thorax, fo that the lungs floated in purulent ferum, and their external membrane and pleura were greatly thicken-ed, and found to be converted into a whitifh cruft, like melted tallow grown cold.

Converfion alfo of fifh.

Surface of the lungs.

The only difference on comparing this fubftance with

that formed in the cemeteries of Paris was, that where large maffes of bodies are inhumed the concrete oily matter or fpermaceti appears in the form of a foap, whilft in thofe immerfed in water the ammonia is not formed, or if formed, is diffolved and carried away by the fluid in proportion as it takes place.

Human fœtus.

The human fœtus has been likewife found to be converted into a fatty fubftance from remaining in the liquor amnii, and there is a fimilar fubftance to be met with in that liquid which is depofited upon certain parts

And the cafeous matter found upon it.

of the fœtus, called by Bunifa and Vauquelin the cafeous matter, it is fuppofed to be a converfion of the albumen. *Vide* article Liquor Amnii.

This converfion of animal fubftances into an oily matter refembling fpermaceti may be produced artificially, by means of the nitric acid; for an account of which, *vide Animal oils.*

It appears, therefore, to be this ftate that all animal matters pafs into under certain circumftances, *i. e.* when the external air is prevented from acting upon them fo as to have no influence on their decompofition, either by their being heaped together in large maffes, by partial exficcation, by water, or by nitric acid.

Explanation.

To account for the changes animal fubftances undergo on being converted either fpontaneoufly or artificially, into this fingular matter, which is a more fimple ftate of compofition, the quantity and proportion of the primitive materials of the different animal fubftances fufceptible of it muft be previoufly known, and fcarcely nothing has yet been done in chemiftry to afford this knowledge. The component parts of animal matters may, however, be reduced, as before obferved, to oxygen, carbon, hydrogen, and azot, for the fulphur, phofphorus, lime, and foda, contribute nothing, according to Fourcroy, to their formation, if the phofphat of lime be excepted, which

conftitutes bones, and which has no influence on the above change. According to modern chemiftry, the foft animal matters, the fkin, mufcles, ligaments, &c. may be regarded as different kinds of carbonated oxyd of hydrogen and azot, and thefe oxyds, more complicated than thofe of vegetable fubftances, tend even more on that account inceffantly to alteration; the equilibrium of their combination is eafily deftroyed, and this is brought about by the leaft changes in the temperature and humidity that furround them. Thefe inconteftible principles being laid down, the decompofition of thefe matters and the formation of the fat may be explained in the following manner.

The carbon efcapes in great quantity in the form of carbonic acid gas, either by reacting on the aqueous part, or by fimply abforbing the oxygen they contain. This volatilization of the carbon with the oxygen is the principal caufe of the confiderable lofs animal fubftances undergo in their converfion into *fat*, for this laft only forms the tenth or twelfth part of every body. The azot, a principle fo abundant in thefe fubftances, combines with the hydrogen, and forms ammonia, one part of which is difengaged in vapours, whilft the other part remains fixed in the fat; the refiduum of thefe fubftances thus deprived of a great part of their carbon, of their oxygen, and of all their azot, which laft no longer exifts in well formed fat, is found to contain a much larger portion of hydrogen, and it is thus carbonated and flightly oxydated hydrogen that conftitutes this peculiar concrete oily matter, or adipo-wax, as it has been called, the union of which with the ammonia forms the animal foap called *fat*. There only remains to determine whether it is the oxygen contained in the animal oxyd, or that which forms a conftituent part of the water, that ferves to compofe this oxyd, in order to bring about the decompofition: and to accomplifh this, two facts are wanting, viz. the exact proportion of

the animal oxyd, and that of the fat at the moment it is formed, and 'which further experiments muft provide, although Fourcroy feems to be of opinion, that from the confiderable proportion of hydrogen exifting, whether in the ammonia formed or in the adipo-wax, it might give reafon to fuppofe that the decompofition of the water is neceffary to this fpontaneous operation.

Having given an account of the different fpecies of putrefaction, it will be neceffary, before concluding the fubject, to take a view of one of it's productions, which, from the dangerous tendency or fatality of it's nature, *Miafmata,* has at various periods of time fpread alarm and terrour in the fou:ce of infection. all ages, and almoft in all countries; this is the putrid matter which is the fource of infection.

· Amongft the evils to which the living body is expofed, the moft dangerous perhaps are to be met with when the atmofphere we breathe is rendered pernicious by the generation of thofe deftructive putrid exhalations which produce difeafes, commonly called peftilential ; and as thefe caufes are too fubtile to be difcovered by any of our fenfes, and are only made known by fatal experience, it is from chemiftry alone we can hope for relief, and by inveftigating the nature of fuch caufes, collect means in order to prevent, mitigate, or deftroy them.

But little underftood. Perhaps no fubject is lefs underftood ; it may be faid to be involved in impenetrable darknefs ; while other fubjects of inquiry have, in the progrefs of human reafon, at leaft been attempted to be invefligated, the remote caufe of infection has remained a fubject of doubt, a difmal fomething upon which fcarcely a conjecture has been made, the origin of which no one durft hazard to invefligate, and of which the operations appear to be capricious, multifarious and unaccountable.

Their production. It is well known, that during the fpontaneous decompofition of vegetable, vegeto-animal, but more particularly

of animal fubftances, a gafeous invifible matter (as be-
fore obferved) is extricated ; and this is capable of acting
more or lefs powerfully on the living animal body, and
of producing different degrees of difeafe, from the com-
mon intermittent or ague, to the moft terrible of all dif-
orders the plague, and when this vapour is in it's moft
concentrated ftate, it's poifon is fo deleterious as to pro-
duce immediate death. This poifonous effluvium is called
miafma, or perhaps more properly, *miafmata*. It is found
to exift in low marfhy and fwampy grounds, in and about
the environs of cemeteries in which numerous bodies
have been inhumed, and wherever large quantities of ve-
getable, or vegeto-animal, or animal matters are expofed
to the open air under a hot fun, fo that they may attain
their higheft degree of putrefaction. It differs however
in it's virulence ; thus in the northern climates where the
procefs of putrefaction is very flow from the acceffories
being moderate, the difeafes miafmata produce are gene-
rally agues, and they feldom extend beyond dyfentery ;
but in the eaftern parts, as in Bengal, on both fides of the
Ganges, in Louifiana, overflowed by the Miffiffippi, and
in Egypt, covered annually by the Nile, when the waters
retire and leave behind them the mud and flime, the
great heat of the fun acting with unremitting force upon
the relics which teem with myriads of animal beings, the
miafmata produced are fo virulent, as to give rife to the
moft dreadful peftilence, and in the moft deadly form.

The term *infection* has been generally employed as fy-
nonymous with *contagion*, and often with *miafmata* ; but
feveral authors of late, particularly Dr. Baily, an eminent
phyfician of New York, who firft made the diftinction,
have employed thefe terms to exprefs different meanings ;
and Webfter has adopted the fame diftinction. They
affirm, that the circumftances that characterize *infection*

Diftinction
made be-
tween in-
fection and
contagion.

are, that it produces epidemics that extend over immense tracts of country; that it's diseases are not easily communicated out of the pestilential atmosphere, and that it is mitigated, suspended or destroyed by cold. On the contrary, the principal features of *contagion*, are, that it produces diseases, but not to any great extent, that they propagate themselves, and that it is favoured by cold. They assert, that the fever which owes it's origin to certain connections with the putrefaction of dead vegetable and animal matters, shows no disposition to propagate itself, whilst the fever arising from a connection with the living human body in a certain diseased state, as in meazles, smallpox, &c. multiplies with great activity. The one is peculiar to particular states of the climate, exists generally in the autumnal months, in hot climates, and but rarely in cold, although it has appeared from general changes in the climate, even in the more northern regions; the other is not peculiar to season or climate, appears oftener in winter than in summer, and in temperate than in hot climates; but as it depends upon adventitious causes, it sometimes commits ravages in summer, and has even appeared in the torrid zone; the one originates from natural sources, the other from artificial ones; such is the general hypothesis of this distinction, the conclusion of which is, that infectious diseases arising from miasmata are not communicated, whilst contagious diseases are.

Ancient and modern opinions on the contagion of pestilential diseases.

A variety of authors have contended for and against the contagion of pestilential diseases; among the ancients, Galen, Aristotle, Thucydides, Seneca, Forestus, Prosper Alpinus, Diemerbroeck, Sydenham, and others, contend, that the plague as well as other pestilential diseases is contagious; whilst Procopius, and those who oppose the doctrine of contagion, not only produce as authority, the silence of Hippocrates, Avicenna, and

other Arabian phyficians, on the fubject, but they affirm,
that if the plague was a contagious difeafe, it would *always*
infect thofe who communicated with the difeafed.

Amongft the moderns, befides the two already men-
tioned, Dr. Smith, of America, and Dr. Maclean, have
fupported the fame opinion. The latter, in a fmall trea-
tife, has attempted to prove that the plague, dyfentery,
and other epidemics, are never propagated by contagion,
for only a very fmall portion of thofe that have been ex-
pofed to the action of the effluvia of the deceafed are
ever affected by the diftemper; he concludes thofe difeafes
only to be contagious which muft neceffarily act and
communicate the difeafe within a certain diftance, as the
fmallpox, meafles, and which can only be received once
by the fame perfon; whilft the others, which may affect
a perfon feveral times during his life, are caufed by certain
ftates or viciffitudes of the atmofphere only. He affirms,
that the exiftence of contagion in the plague, dyfentery,
and fevers, has been uniformly taken for granted, not only
without proof, but even contrary to the evidence of nu-
merous and convincing facts.

Although thefe and feveral other phyficians of emi-
nence, particularly Dr. Rufh, of Philadelphia, whofe
opportunities of obferving the yellow fever, or plague, of
America, have been very great, are of opinion, that pef-
tilential difeafes arifing from miafmata are not contagious;
yet as fuch opinions may as yet be looked upon as con-
jectural, without any direct, explicit, and perfectly decid-
ing facts, to place fuch opinions beyond the reach of all
doubt and controverfy, it would be highly improper in the
prefent ftate of knowledge on this fubject, for either the
magiftrate or the phyfician of a board of health to di-
veft themfelves of the leaft precaution, either by putting
an end to quarantine, or by not applying to every other

means that might place the safety and welfare of their
fellow citizens beyond every the slightest suspicion and
fear of such terrible calamities.

Among the numerous opinions given respecting the
causes of pestilential diseases, whilst some have even de-
nied the existence of a putrid cause, others have been so
convinced of it's presence as to describe even it's pecu-
liar smell.   Those who have had infectious air fresh in
their nostrils affirm, it is easily distinguished from all
other known odours; but the different accounts they give
of it may afford some reason to suspect them of errour. Some
call it an earthy smell, very disagreeable, that it in some
measure affects the organ of taste, even extending into
the stomach ; others have compared it to the vapours
issuing from a newly opened grave, but without the cada-
verous stench; others think it resembles the effluvia of
rotten straw ; and others again are of opinion it is like
the exhalations from the confluent smallpox at the turn
of the pustules.   The gravediggers mentioned by Four-
croy spoke of the odour from the bursting of the lower
belly, in a state of great putridity, to be a horrible stench ;
and whenever they are exposed by an unfortunate chance
to bodies in the earth, in this dangerous state, so great is
it's poisonous activity, that if near, they are immediately
struck with asphixy ; if at some distance, it only gives
them a slight vertigo, a disagreeable sensation of fainting,
or of nausea, which continues several hours, followed by
loss of appetite, weakness, and tremours ; hence arise
those diseases which people are subject to who live in the
neighbourhood of large cemeteries, a great number of
whom have their countenances pale and wan, with other
symptoms announcing the action of a slow poison. From
the circumstances, however, in which this poison is ex-
tricated, it is perhaps, never admitted to the organ of

fmell in it's pure form, but generally accompanied by fome other gafeous and difagreeable emanation, that may have given rife to the different opinions of it's odour.

With refpect to the manner in which contagion is communicated, Dr. Carmichael Smith is of opinion, that it is not only from a direct communication with the fick that contagious fevers are propagated, but that unfortunately the perfons and clothes of thofe who remain long in a contagious atmofphere, and the excretions of the fick, are capable (even when conveyed to a great diftance, or preferved for a length of time) of producing the fame mifchief as an immediate communication with the fick themfelves, and that the jail diftemper and putrid contagion are thus frequently conveyed cannot, he thinks, be denied. Indeed, wherever a vapour can be diftinguifhed by the fmell, we have the demonftration of our fenfes, for what a length of time, not only clothes but furniture, and even the boards and walls of houfes will retain it; therefore, in refpect to the jail or hofpital fever, it may be fafely affirmed, that it not only attacks thofe immediately expofed to the original atmofphere, but that this contagion may be certainly communicated by the clothes of thofe that have been any length of time confined in it; and what is more furprifing, even when the perfons themfelves are not affected. Indeed, the dread of thefe terrible difeafes may have probably magnified the danger beyond reality, and the rifk of propagating the contagion may not be fo great as is fuppofed; phyficians, and even apothecaries not being fo long expofed to this atmofphere as to be in great danger of conveying the contagion elfewhere, yet the perfons, and efpecially the clothes of nurfes and affiftants, who are conftantly confined amongft the fick, are certainly capable, according to Dr. Smyth, of communicating the difeafe; but he adds, that however paradoxical it may appear, he never obferved that the

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fick propagated the difeafe fo readily as the ·bodies and clothes of thofe, who, though well, had been long confined in the original atmofphere. He is of opinion, that unlefs where contagion is very powerful, it is feldom propagated in the open air, and he knew only of one inftance of this, at the prifon of Winchefter. He thinks there is but little rifk of receiving contagion from the diffection of dead bodies, unlefs when the operator happens to cut himfelf.

The perfons moft fufceptible of this contagion, Dr. Smyth afferts, are young perfons, particularly if they come directly from a pure air into the infected atmofphere, thofe whofe minds are oppreffed with fear or anxiety, or who have been weakened by previous illnefs ; even thofe who have been fatigued, or are fafting, receive it more readily than others whofe ftrength has not been impaired, or which has been again recruited with food. A moift atmofphere is alfo more favourable to the communication of contagion than a dry one, and a contagious perfon becomes greatly more fo, if his clothes are wet, and his body heated by exercife fo as to be in a ftate of perfpiration. It has likewife been remarked, that perfons who have iffues are feldom affected by contagion.

Putrid matter, in whatever way generated, if in fufficient quantity, has always fome deleterious effect acting as a poifon upon the body ; and this effect takes place whether the putrid matter be generated in the body, taken into the ftomach, or into the blood by means of a wound. It is true, the human ftomach, and ftill more remarkably, the organs of digeftion of certain animals, have the power of counteracting the feptic tendency ; but this power, at leaft in the human ftomach, is very limited, and when any matter, whether generated in the body or introduced from without, has acquired a degree of putridity beyond this, it occafions naufea, vomiting, purg-

ing, great oppreffion at the region of the ftomach, and often a fever, either of the intermittent, remittent, or more continued kind. Putrid matter directly introduced into the fyftem by means of a wound caufes fwelling, and inflammation of the lymphatic glands, often terminating fuddenly in gangrene, along with the fymptoms of a fever, greatly refembling the hofpital or jail fever; the fame proftration of ftrength, tremors, anxiety, headach, and delirium, and all the fymptoms of a bad putrid fever, as petechiæ, hemorrhage, indicating a certain decompofition of the blood. The fevers that arife from expofure to putrid vapour or contagion affume a variety of types and forms, according to the degree of putridity, feafon of the year, conftitution of the patient, &c.; but they as well as the preceding will be found to have many fymptoms in common, and fimilar to the jail and hofpital fever; and in reality, all the fevers of this clafs, from the flighteft vernal intermittent to the true plague, are, as Dr. Smyth obferves, only different fhades or varieties of the fame difeafe, and productions of one common caufe, viz. putrefaction.

What that fubtile or powerful vapour, or whatever elfe it may be, is that arifes during the putrefactive procefs, and acts in the form of fuch a powerful poifon, is unknown. Various, however, have been the opinions on the caufe of peftilential fevers.

On extending our inveftigation towards antiquity re- fpecting the origin of peftilential difeafes, we fhall find that fuperftition was the firft to account for them, by afcribing peftilence to the immediate exercife of Divine Power. It was fuppofed that it was one of the judgments that God inflicted on mankind in his wrath, to punifh them for their iniquities; thus when Daniel was fummoned to receive his punifhment for numbering the

children of Ifrael, having been permitted to make choice of the three greateft calamities, he preferred, for a pious reafon, peftilence to either famine or the fword; and 70000 of his fubjects perifhed. " I will fmite the inhabitants of this city both man and beaft, they fhall die with great peftilence." 2 Sam. 21. Jerem. ch. 21.

Homer.

In perhaps the oldeft hiftorical account of mankind, after the Bible, we are informed by Homer, that a plague raged during the fiege of Troy, and peftilence is afcribed by the poet to extreme heat under the influence of the dog-ftar, and alfo to vapours.

" As vapours blown by Aufter's fultry breath,
" Pregnant with plagues, and fhedding feeds of death,
" Beneath the rage of burning Syrius rife."

POPE's Hom. Il. b. 5. 1058.

Hippo-
crates.

Hippocrates attributes peftilential difeafes to putrid air, which infects all animals that breathe in it. " Firft," fays he, " I will begin with the moft common febrile difeafe, which in fome meafure accompanies all difeafes; for there are two forts of fevers, one that is promifcuous, and common to all, called the plague; the other, by reafon of unhealthy diet, is peculiar only to fuch as ufe that diet; but of both thefe kinds of fevers the *air is the fole author and caufe*; the common fever or plague therefore happens to all, becaufe all breathe the fame air; and it is certain, that the fame air being mingled in fimilar bodies muft beget the like fevers." On demanding why infectious diftempers feize not all animals alike, he anfwers, that when the air is filled with fuch filth and pollutions as are noxious to human nature, men only fall fick, but when it is hurtful to any of the other fpecies of animals the difeafe feizes that fpecies only. Hippocrates, however, feems to have been aware that there was fomething elfe neceffary, for he fpeaks of το θειον or fome divine

principle in the air, which has been fuppofed to mean an epidemic conftitution, arifing from changes in the atmofphere produced by unknown caufes.

According to the obfervations of Ariftotle, peftilence Ariftotle. may owe it's caufe to a hot and dry fouth wind.

Galen, who lived at Rome in the reign of Marcus An- Galen. toninus, whilft a raging plague was defolating that city, is of opinion, that Hippocrates was miftaken in afcribing the caufe of epidemic difeafes to the air only, and obferves, that peftilential fevers fometimes proceed from a great abundance of humours, whenever thefe have acquired from the ambient air the leaft tendency to corruption. He attributes alfo thefe difeafes not only to the air, but to unwholefome food and vitiated waters.

Ammianus Marcellinus mentions a plague in the city Marcelli-of Amida, in Perfia, when befieged by Sapor, about the nus. middle of the fourth century ; it arofe from the corruption of numerous dead bodies which lay unburied in the ftreets. He then proceeds to give the opinions of others on the fubject, as follows: " Philofophers and eminent phyficians have taught, that peftilence is produced by excefs of heat or cold, of drought or moifture. Hence thofe that live near wet and marfhy places are fubject to coughs, difeafes of the eyes, &c. Thofe, on the other hand, that refide where the heat is great, are troubled with febrile complaints, and in proportion as the matter of fire is more active, drought is more rapid in deftroying life. Others are of opinion, that air, like water, vitiated by the effluvia of dead bodies, or fimilar fubftances, is deprived of it's falubrity, or at leaft, that a fudden change of air will produce the more flight complaints. Some alfo affirm, that the air, rendered grofs by a denfer vapour from the earth, clofing the pores of the body, and checking perfpiration, becomes fatal to the lives of others, for which reafon thofe animals which are continually

bending towards the earth are the firſt victims to peſti-
lence, as Homer teſtifies, and which is proved by many
examples during the prevalence of peſtilential diſeaſes."

Ætius.

About the cloſe of the fifth century, Ætius, who was an
eminent phyſician, has compiled the opinions of his pre-
deceſſors on epidemic diſeaſes. "Thoſe are ca'led ſo,"
ſays he, "which originate from a common cauſe, as bad
food, or water, immoderate grief, or want of cuſtomary
exerciſe, hunger, or repletion, eſpecially when abundance
ſucceeds extreme want. But the nature of the country
often cauſes epidemic diſeaſes; the air we breathe being
vitiated by the evaporation from putrid ſubſtances, ſuch
as multitudes of dead bodies after battles, marſhes or
ſtagnant water in the vicinity, which emit poiſonous
and fetid vapours. This cauſe is in continual operation."

Proſper Al-
pinus.

The Greeks called thoſe diſeaſes that operated univer-
ſally επιδημικοι, and if at the ſame time they were very de-
ſtructive, they had the name of a plague, by the Greeks,
λοιμος, by the Latins, peſtis, à paſcendo or peſtilentia, ac-
cording to Iſidorus, quàſi paſtulentia, quòd veluti incen-
dium depaſcit, becauſe it conſumes and devours like a
burning flame But ſince, although at what time is diffi-
cult to ſay, a difference has taken place between *peſtis* and
peſtilentia. It is, however, found in the works of Proſ-
per Alpinus, a Venetian phyſician, who wrote about the
cloſe of the 16th century. This author maintains, that
peſtilent fevers are occaſioned by local cauſes, as vitiated
air, and by peculiarities of ſeaſon, as extreme heat and
humidity; but he aſſerts, that the plague in Egypt rarely
proceeds from corrupted air, and never except after an
unuſual flowing of the Nile, and concludes, it is uſually
imported.

Diemer-
broeck.

An eminent Dutch phyſician of the laſt century,
Diemerbroeck, aſſigns three cauſes of the peſtis or true
plague. 1. The juſt anger of Heaven, provoked by ex-

halations from the finks of our fins and abominable deeds.
2. A moft malignant, poifonous and deadly peftilent
germe, like a fubtle ferment or leaven, fent from Heaven
in a very fmall quantity, diffufing itfelf through the air
like a fubtle gas, and rendering it impure. This gas, he
fuppofes, fpreads over many regions, and impreffes, by
it's numerous particles on the air, an infection like poi-
fon, which affects people.

He maintains the diftinction mentioned by the laft
author, and fuppofes, that peftilentia is produced by
exhalations and intemperate feafons; whilft the plague,
he contends, cannot be occafioned by thofe caufes,
though they may affift the germe or general caufe.

According to Van Helmont, a Flemifh writer of the Van Hel-
laft century, the plague cannot be afcribed to the unfea- mont.
fonable changes of times, nor to putrefaction; but that
it's poifon is a fecret, that the matter of that difeafe is a
wild fpirit tinged with poifon, exhaling from a difeafed
perfon, or drawn inwards from a gas of the earth, putre-
fied by continuance, and receiving internally an appro-
priate ferment, and by degrees attaining a peftilential
poifon in us. The remote, crude, and firft occafional
matter of the peftilence, is an air putrefied through con-
tinuance, or rather a heavy putrefied gas, which putre-
faction of the air hath not the 8200th part of it's feminal
body. When we compare this unintelligible explanation
of this alchemift with the ancient method of afcribing
the caufe of peftilential difeafes to the extravagant fyftem
of judicial aftrology, the latter is by far the moft fatis-
factory; both of them perhaps equally unphilofophical.
The author, however, contends againft a more ancient
fuperftition, that the plague is not fent down from Hea-
ven, but that popular plagues draw their firft occafional
matter from an earthquake, and from the confequences of
camps and fieges.

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Hodges.

Hodges, who wrote a treatise on the great plague in London in 1665, observes, that the air suffers some essential alteration which is necessary to favour the propagation of pestilence. The nitro-aerial principle, which causes or invigorates animal and vegetable life, sometimes becomes imperfect, degenerate or corrupt, being tainted with something pernicious to vitality. He calls it poisonous, and observes that it proves injurious to trees and cattle, as well as to man. He supposes the corrupting principle to be a subtle aura, or vapour, extricated from the bowels of the earth.

Van Swieten.

According to Van Swieten, the cause of epidemics is in the hidden qualities of the air, and is inexplicable.

Sydenham.

Sydenham agrees with Diemerbroeck, and Van Swieten, in ascribing pestilence to occult qualities in the air. Of the same opinion is Fernelius, Sennat, and Stenkius.

Mead.

Mead ascribes the plague to the putrefaction of animal substances and unseasonable moistures, heats, and want of winds; and affirms, that no kind of putrefaction in European countries is ever heightened to a degree capable of producing the true plague. He is surprised that authors should have recourse for an explanation of the causes to hidden qualities, such as malignant influences of the heavens, arsenical, bituminous, or other mineral effluvia, with the like imaginary or uncertain agents. He assigns three causes. 1. Diseased persons. 2. Goods transported from infected places. 3. A corrupted state of air. He does not, however, deny all latent disorders in the air, but considers them as secondary causes only, increasing and promoting the disease when once bred, and thinks infection to be the means of it's propagation. In this he differs greatly from Diemerbroeck, who utterly denies that the disease is originally derived

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from infection, although he agrees that it may be after-
wards communicated from perfon to perfon by contact,
or near approach. Diemerbroeck alfo maintains the
latent qualities of the air to be the *principal* caufe of
the plague, or caufe, *fine qua non*. Mead fays, the
plague is never originally bred with us, but always brought
accidentally from abroad.

Mackenzie, who gave an account of the plague in Macken-
Conftantinople, fuppofes the difeafe to proceed from zie.
venomous moleculæ, lodged in wool, cotton, hair,
leather, and fkins, in houfes not well cleanfed after
peftilence. He thinks the air no otherwife concerned
in producing the difeafe, than as a vehicle to convey
the venomous particles from one body to another.

The idea of Dr. Chandler greatly refembles that of Chandler.
Dr. Mackenzie, with refpect to the origin of plague.
He fays it might be perhaps truly defined, a difeafe
arifing from certain animalculæ, probably invifible,
which burrow and form their nidus in the human body.
They always fubfift in places fuited to their nature. The
fpecies imported from Smyrna are commonly deftroyed
by intenfe heat. The pores of the fkin opened by the
weather, readily admit them.

Gibbon the hiftorian afferts, that the plague arifes from Gibbon.
hot, damp, ftagnant air.

The Abbe Fourmont, that it originates from famine. Fourmont.

Dr. Mitchill, that the gafeous oxyd of azot or nitro- Dr. Mitch-
gen is the matter of contagion; this is the dephlogifti- ill.
cated nitrous air, difcovered by Prieftley, it fupports flame
and extinguifhes life.

It might have been expected that in defcending to
modern times, a more fatisfactory account of the poifon-
ous matter, whofe action has been fo very inimical to
the human fpecies, would have been given by phyfici-
ans, but it appears, that no method has yet been found

out to render this invisible agent pervious to the senses, and that every thing respecting it hitherto has been either fable or conjecture. If, however, this terrible enemy has escaped the investigation of the philosopher, means have been employed to render the poison ineffectual, and to discover by chemical reagents what are the most effectual substances to counteract it's effects, either by decomposition, or chemical union.

Ancient use of fumigations, descending to modern times.

Hippocrates, we are informed, in order to destroy the pestilential particles of the air, made use of scented wood, which he caused to be burned in piles placed at the corners of the streets, but the remedy appears to have been equally as inefficacious as the smoking of tobacco, the thieves vinegar, with the rest of the numerous nostrums and amulets that have succeeded each other at different times. It is readily conceived why fumigations, and substances yielding strong odours, were first employed for this purpose. The plague, and other diseases, attended with great mortality in ancient times, being considered by the superstitious world, as judgments sent by the hand of divine vengeance, to scourge the human race for their sins, as before observed, sacrifices and expiations were made to the gods, to deprecate their wrath, and atone for the guilt of mankind. Sweet smelling herbs and flowers, and aromatic gums, as myrrh and frankincense, were therefore burnt during these ceremonies ; and as the whole were of an agreeable odour, and overpowered the offensive effluvia of diseased or corrupted bodies, it was natural for these ignorant people to believe, that such fumes, by destroying the smell, destroyed likewise the polluted effluvia. Another circumstance observed by Dr. Trotter might have given rise to similar means. It was believed that the pestilential diseases were the offspring of putrid and of putrefying animal and vegetable substances, and these substances

they saw became the nidus and the nourishment of nu-
merous young insects; whence they concluded, that
their generation was spontaneous. To destroy these ani-
malculæ, which in hot countries increase in such
numbers, and which now on the wing they con-
sidered as polluting the atmosphere, brimstone and
fire would soon be resorted to, as it was known, that
no animal could approach their conflagration, so that
every article that yielded either agreeable odours or
pungent vapours was employed; hence the hyssop of the
wall, the cedar of Lebanon, the camphire of Engedi,
spices and the pitch of Norway, and the tobacco of Vir-
ginia, swell the antipestilential catalogue; and the fumi-
gating substances have been handed down from the
Jews, the Greeks, and the Romans, through the Arabian
physicians and the dark ages of Europe to the moderns,
and have maintained their reputation and character,
amidst all the vicissitudes of human opinions, and the
fleeting duration of medical theories. Nobody, till late-
ly, has questioned a practice sanctioned by the authority of
antiquity, and the universal suffrage of modern physi-
cians, until the beautiful discoveries of pneumatic che-
mistry, which explained the nature and composition of
elastic fluids, invited the chemical philosopher to apply
his new acquired knowledge to the detection of the causes
of pestilential diseases, and to find out the best and most
suitable prophylactics against them.

Until a knowledge of the different airs that compose
our atmosphere, and the various gases that arise from
spontaneous or artificial decomposition, began to prepare
the chemist for future investigation, little could be ex-
pected from any other branch of philosophy, but no
sooner did the experiments of Black, Cavendish, Priest-
ley, Lavoisier, and Berthollet, afford a light into the un-
explored regions of the aerial world, than a new oportu-

Chemical method of destroying miasmata.

nity prefented itfelf of inquiring into the nature and
properties of thofe effluvia, that arofe from the putrefac-
tion of animal and vegetable fubftances, and which have
in all ages been more or lefs looked upon as the origin of
peftilential difeafes.

Morveau.   Amongft thofe who made the firft attempts to render
the poifonous vapour of peftilence ineffectual by chemical
decompofition, Morveau, a chemift of Dijon, is perhaps
the beft deferving of being recorded. He appears to
have confidered this matter as compofed of volatile alcali,
and an acrid animal oil in a gafeous, or aeriform ftate ;
and he informs us, that in May, 1773, the cathedral
church of Dijon was found to be fo very infectious and
noifome, from the numerous inhumations, as to be no
longer fafe to frequent, whilft various fubftances had
been employed to deftroy it's cadaverous fmell, fuch as
large quantities of aromatics, vinegar, nitre, but without
any effect, and under thefe circumftances this chemift
was applied to.

It is a well known property of the muriatic acid, to
take a gafeous form as foon as it is difengaged from it's
combinations, but without lofing it's acid character, or
having it's energy diminifhed, and this was found to be
of great ufe in purifying and deftroying the infection of a
mafs of air, when loaded with putrid vapours. The
method the commiffaries of the Royal Academy at Paris
had employed, in their report on the prifons of that city,
was to add vitriolic acid to common falt, which difen-
gages the muriatic acid in the form of white vapours,
that immediately expand throughout the whole room
or place where the procefs is made ; and this has been
found, to ufe the expreffion of thefe commiffaries, to
neutralize the putrid miafmata, and they recommend, as
foon as the vapours are paffed away, the doors and win-
dows to be left open for two or three days, fo that the

flight odour of the marine acid remaining may be dif-
fipated, after which they found not the leaft danger of
immediate habitation.

Morveau, with this previous knowledge of the good ef-
fects of this acid, applied it to the prefent inftance of
the cathedral. He fuppofed, that the acrid animal oil
of the putrid effluvia, and which particularly affected the
organ of fmell, was fupported in it's gafeous form by the
volatile alcali, and that if a decompofition could be
effected, the heavy fetid oil would fall down and be ren-
dered inert. The vitriolic acid, formed by the combuf-
tion of fulphur, he knew would to a certain point ac-
complifh this object; but as it rifes very little, and after
feizing upon the humid vapour, which it does with great
avidity, lofes it's heat and falls down again, it was incom-
petent to the tafk. He therefore placed a glafs veffel
prepared for the purpofe in the middle of the church,
put into it 6lb. of common falt fomewhat moiftened,
and poured 2lb. of common vitriolic acid upon it, and
immediately retired. He informs us, that he was
fcarcely got four paces, before a column of vapours of the
muriatic acid had reached the ceiling of the church, and
two hours afterwards, it was perceived through the key-
hole of the moft diftant door. In about twelve hours all
the doors were opened for the air to be cleanfed of any
remaining acid, but there was no longer any trace of pu-
trid odour to be perceived.

The following year, another proof of the fuccefs of the
fame method was made in the prifons of Dijon. We
are told, that 31 prifoners had died of the peftilential
difeafe, called the jail fever, in lefs than three months,
and means had been in vain attempted to deftroy the ca-
daverous odour, by burning ftraw in the prifon, but in
twelve hours after the operation of the muriatic acid, the
fetid odour was entirely deftroyed, the danger of in-

habiting it no longer exifted, and from that moment, the epidemic fever entirely ceafed.

Others who have been employed in purifying infectious places, in confequence of epidemic difeafes, recommend the fame procefs, and advife it to be ufed as a precaution every year to preferve in particular the falubrity of prifons, and deprive them of infection.

Another form in which this acid has been employed, Fourcroy. is in it's dephlogifticated ftate. According to Fourcroy, whatever care is taken to keep anatomical theatres clean and inoffenfive, either by fprinkling with vinegar, or by fumigations, it is found very incapable of preventing the dangerous effects arifing from a large mafs of matter, in a ftate of putrefaction; this enemy is the more terrible to anatomifts, whofe occupation is to refide within the reach of it's action, and the frequency of accidents from this fource every year is well known. To oppofe, therefore, an impenetrable barrier to this deftructive agent, to prevent it's difaftrous effects on thofe occupied in anatomical purfuits, and to deftroy the germe of putrid and frequently fatal difeafes, which thefe miafmata occafion, this chemift recommends the oxygenated muriatic acid, which he found to be the beft fhield againft the poifon of all animal putrefaction. He was led to it's ufe, from the effects it was found to have on odours of all kinds. Aromatics, the acid antifcorbutic, the poifonous narcotic, hepatic and fulphureous odours, were all deftroyed by this vapour, and as it acts immediately on the odorous principle, alters it's nature, and changes rapidly the order of it's compofition, it was fuppofed, that it was likewife capable of oppofing thefe dangers arifing from the miafma of putrifying bodies, and this chemift informs us, experience confirmed the fuppofition.

Another acid which was first employed by Dr. Car-
michael Smyth, to destroy the contagion of the hospital
fever, or jail distemper, is the nitrous acid. The cause
of this fever he attributes to putridity. As a proof of
this, he observes, that this disease is constantly produced
where a number of people are shut up together in a
close place, without the greatest attention to cleanliness
and renewal of the air. Now it is well known, that
all the excretions of the human body have already made
a certain advance or progress towards putridity, and that
when placed in certain circumstances favourable to putre-
faction, they soon become highly putrid; amongst these, he
thinks none is more highly animalized or more susceptible of
becoming putrid than the perspiration or vapour issuing
from the surface of the body and lungs; hence the animal
perspiration may generate contagion, which contagion is
found to show it's baneful effects more quickly and for-
cibly in proportion to it's quantity, and it's being
placed in circumstances the most favourable to putrefac-
tion; consequently, in proportion to the size and close-
ness of the place, the temperature and moisture of the
air, and the additional or accessory putrid matters with
which it is combined; whilst on the contrary, the for-
mation of this contagion is prevented by all those means
that renew the air, and carry off the perspiration, or
prevent it's tendency to putrefaction. In order to destroy
the sceptic nature of this jail or hospital contagion,
which he looks upon as one of the most subtile and
powerful vapours of the putrid kind, from it's immediate
and destructive effects on the human body, several ways
were employed. At first, when Dr. Carmichael was
requested to undertake the cure of this disease, which
was raging with great violence during the spring and
summer of 1780, amongst the Spanish prisoners, confined

in the King's houfe at Winchefter, he found great be-
nefit from cleaning the parts of the prifon affected by
the contagious matter, wafhing the hammock pofts with
diluted muriatic acid, and throwing it by machines to
the upper part of the pofts, and even as high as the
ceiling, at the fame time the prifoners were well wafhed ;
but the moft important part of the method he employed
is the nitrous acid, which he informs us he ufed in two
different forms, either in vapour from the yellow or
fmoking nitrous acid, or from nitre difengaged by the
vitriolic acid ; by which practice, both in hofpitals, and
in private practice for 16 or 17 years, he has obtained
the moft decifive evidence of it's effects, in preventing
the fpreading or farther communication of contagion.
Having found, that the moft highly contagious fevers in
hofpitals do not effect the patients in general, lodged
in the fame ward, but only the nurfes or thofe who
affift them, or thofe who lie in beds contiguous to the
fick, he has repeatedly prevented the farther fpreading of
the difeafe, by placing gallipots filled with the fuming
nitrous acid, betweed the beds of the fick, and of thofe
who were not yet affected by the contagion ; and in
private practice, where the nitrous acid has been con-
ftantly ufed as a fumigation, he has not known one in-
ftance of a contagious fever having been communicated,
even to a nurfe or to an attendant. He is of opinion,
that the well known efficacy of the fulphureous acid in
deftroying contagion, is a fufficient reafon for it's being
continued as a fumigation for clothes, furniture, &c.;
but as the nitrous acid is attended with no rifk, or in-
convenience to the refpiration, and appears of fufficient
efficacy to prevent the progrefs of the contagion, it is
the proper antidote to be applied in all fituations where
perfons are necelfarily prefent ; likewife in purifying
empty hofpitals or prifon wards, or fhips, as it is equally

efficacious with the sulphureous, it's vapour more volatile and penetrating, and it does not leave the disagreeable smell which sulphur does, when burnt. To obtain the nitrous or marine acid, in a state of vapour, as Dr. Smyth is of opinion, that all the mineral acids will destroy contagion, and are much more powerful than the most concentrated vinegar, he advises to decompose nitre or salt by heated vitriolic acid, half an ounce of which is put into a crucible, glass, china cup, or deep saucer; this is warmed over a lamp, or in heated sand, adding from time to time some nitre, or common salt; these vessels ought to be placed at 20 or 30 feet from each other, according to the height of the ceiling, or virulence of the contagion. In hospitals or prisons, the lamps or vessels containing heated sand may be placed on the floor; in ships, it will be better to hang them to the beams by waxed silk cords. As fumigating with nitrous acid is attended with no inconvenience, the process so simple, and the materials so cheap, it should be employed as a means of prevention, for some hours every day, in transports with troops on board, and in crouded hospitals; and if there be any appearance of contagion, the fumigation should be executed with more care and attention, and the vapour confined for several hours at a time. Fumigating vessels or lamps should also be placed contiguous to the hammocks, or beds, of persons affected with any contagious or putrid distemper, and by such precautions great mischief may probably be prevented.

A corroborating instance of the effect of the nitrous acid in stopping contagion is described by the same author. The experiment was conducted by Menzies, surgeon on board the Union hospital ship, which contained nearly two hundred sick, of whom one hundred and fifty were in different stages of a malignant fever, and highly contagious,

as appeared from it's rapid progrefs, and fatal effects. The utenfils and materials for fumigation confifted of a quantity of fine fand, twenty-four great earthen pipkins, and as many fmall common tea-cups, with fome long flips of glafs as fpatulas, the concentrated vitriolic acid, and a quantity of pure nitre in powder. The ports and fcuttles being clofe fhut up, the fand, which had been previoufly heated in iron pots, was fcooped out into the pipkins by means of an iron ladle, and in this heated fand in each pipkin, a fmall tea-cup was immerfed, containing about half an ounce of concentrated vitriolic acid, to which, after it had acquired a proper degree of heat, an equal quantity of levigated nitre was added gradually, and the mixture ftirred with a glafs fpatula, until the vapour arofe from it in confiderable quantity. The pipkins were then carried through the wards by the nurfes and convalefcents, walking about with them in their hands, occafionally putting them under the cradles of the fick, and in every corner where any foul air was fufpected to lodge. In this manner the fumigation was continued, until the whole fpace between decks was, fore and aft, filled with the vapour, which appeared like a thick haze. The body clothes and bed clothes of the fick were likewife expofed to the nitrous vapour as much as poffible, the dirty linen removed, and immediately immerfed in a tub of cold water, dried, and then fumigated before taken to the wafh-houfe, a precaution very neceffary in every infectious diforder; due attention was alfo paid to cleanlinefs and ventilation. The fumigation took up about an hour, and in an hour afterward the vapour having entirely fubfided, the frefh air was freely admitted by throwing open again the ports and fcuttles. The fumigation was repeated morning and evening, and it's pleafing and immediate effect in deftroying the offenfive and difagree-

able fmell, arifing from fo many fick crowded together, was very perceptible; and fo great was the benefit it produced, that not one of the attendants on the fick, or any of the fhip's company, was attacked with the diforder after it was firft begun.

The fuccefs of the fame plan is likewife further attefted by the fubfequent letters of the fame furgeon, and Baffan, who fucceeded him; and from a fimilar experiment made on board fome of the Ruffian men of war.

In making ufe of the nitrous vapour, it is neceffary to diftinguifh that which is good from that which is hurtful. The vapour made ufe of by Dr. Smyth, by means of the vitriolic acid, poured on nitre in earthen or glafs veffels, is white, highly dephlogifticated or oxygenated, and mixed with a large quantity of pure dephlogifticated air; and this fume is not only not fuffocating, but has a pleafant fmell.

The vapour, however, which arifes in the ufual procefs of diftilling aqua fortis, as it is done in iron veffels, or which exhales during the folution of metals by the nitrous acid, is of a red colour, has been called phlogifticated nitrous acid vapour, and is highly fuffocating and noxious; fo that in preparing this vapour caution muft be ufed, that no metallic or inflammable fubftance be admitted to the acid either by means of the veffels, or ufing iron fpatulas or implements.

By this fumigation, therefore, it appears, that the procefs is both fimple and eafy; and although the vapour is extremely powerful and penetrating, the fick of every defcription are obferved to bear it with little or no apparent inconvenience; and as it is found to purify the air from the difagreeable effluvia produced by fo many people crowded together in a confined fituation, of completely deftroying the offenfive fmell, and contagious matter ari-

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fing from putrid animal effluvia, or other animal mat-
ters; it will be peculiarly advantageous on board of
fickly fhips and hofpitals, as well as prifons, where the
clothes of the crew or patients may be fumigated at the
fame time as the apartments, without any rifk of fire. At
the fame time it appears, that the advantages of the fu-
migation are not only experienced by thofe in health,
whom it preferved from the baneful effects of the fever,
but the fick and convalefcents derived an almoft equal
benefit from it; the fymptoms of the difeafe were me-
liorated, and loft much of their malignant appearance,
and the advantage of an air pure and free from ftench
to convalefcents muft be very great.

Dr. Carmichael Smyth has, in a *defcription of the gaol
diftemper*, given an examination of the different means hi-
therto employed to deftroy the gaol contagion. Thefe he
arranges under two claffes, viz. the phyfical and the
chemical. He fays, that contagions, whether fpecific or
putrid, are either checked or completely deftroyed by the
extremes of heat and cold; and by a free expofure to air
and water are fo diluted or diffolved as to lofe their nox-
ious quality. Thefe four are therefore phyfical agents. A
degree of heat nearly equal to that of the oven is found
neceffary for the complete deftruction of contagion, and
may be ufed in purifying clothes, furniture, &c. Heat
is likewife, when judicioufly managed, a check to it's
progrefs; for as clofenefs and dampnefs are favourable to
the production and fpreading of contagion, drying and
rarifying the air, by counteracting thefe, muft be, at leaft
fo far, proper antidotes. Independent, however, of heat,
an open fire, efpecially where the fuel is burnt in a nar-
row flue, is of great benefit, as being one of the beft ven-
tilators. The degree of cold neceffary to deftroy conta-
gion is probably, like the degree of heat, inconfiftent with

life, and therefore, although we hear of contagion having been checked or suppreſſed by cold, there are few instances, if any, of it's being completely deſtroyed by it.

That noxious vapours are hurtful only when concentrated, and are harmleſs when diffuſed, are facts univerfally admitted ; and hence clothes, bedding, or other things to which contagion adheres, are purified by a certain length of expoſure to the open air, or to a current of water ; but as the time requiſite for this mode of purification is uncertain, and as contagious clothes and goods, &c. cannot always be expoſed in a proper manner, the more expeditious means which chemiſtry affords muſt be had recourſe to : and as Dr. Lind has very properly remarked, that no ventilation or admiſſion of air or water into priſons or hoſpitals can remove or deſtroy contagion when once preſent, although both may be uſefully employed in blunting it's force, chemical agents are abſolutely neceſſary. Theſe Dr. Smyth examines. The chemical agents hitherto employed for deſtroying contagion, are,

1. *Burning ſulphur with charcoal, or with arſenic.* The vapour from the burning of ſulphur is remarkably volatile and powerful, and it's effect in deſtroying contagion has been long eſtabliſhed, but as even in ſmall quantities it affects reſpiration, producing ſuffocation and death, it can only be employed for fumigating clothes, furniture, or empty apartments. The occaſional addition of arſenic ſeems to have been made by Dr. Lind, with a view of increaſing the deleterious quality of the vapour ; but it appears unneceſſary, as the ſulphureous acid is ſufficiently ſtrong, and perhaps the vapour of arſenic is too heavy to riſe with the acid of ſulphur.

2. *Burning or deflagrating nitre.* As there is no nitrous acid produced, it can be of no uſe except ſo far as the oxygen may be of ſervice.

3. *Burning gunpowder* and port-fire (one half sulphur, one quarter nitre, and as much charcoal) can be of no use.

4. *Tar, tobacco,* and *wood* when burnt (although Dr. Lind appears to have had a high opinion of the second, and looked upon the third to be one of the most powerful means of destroying contagion) cannot be of any service.

5. *Vinegar.* This, although much boasted of, Dr. Smyth never saw of any service; but the steam when united with camphor affords a reviving smell to patients. Washing the furniture, floors, and walls with vinegar, is little better than common water, and the same may be said of white washing, and oil painting.

The most powerful agents, perhaps, after fire, are the mineral acids, particularly when in a state of vapour, with the different gases or permanently elastic fluids produced by them; and as they are known to have a great influence over putrefaction, and those other spontaneous changes which vegetable and animal matter, deprived of life, undergoes, they certainly must be very efficacious in destroying the gaol contagion, which, according to Dr. Smyth, is a vapour produced by putrefaction.

As the volatile sulphureous acid vapour, though effectual in destroying contagion, cannot be employed except in situations from which people can be removed, Dr. Smyth made some experiments with the vapours of the other acids upon mice, birds, and upon himself; and found the different acid vapours, in respect to the safety with which they can be breathed, may be arranged in the following order:

1. *The vapour of nitrous acid, arising from nitre decomposed by vitriolic acid.* This is perfectly harmless in any quantity in which it may be required, there not being the least risk in breathing it. For this purpose, the fumigating lamps sold at Moyser's, in Greek street, Soho, may

be employed, a great number of which are fold to the navy, but they would anfwer much better if the faucer was deeper ; and if, inftead of a place for a lamp, there was a box proper for containing hot fand, in which the faucer might be placed. This nitrous vapour appears to be the *defideratum* fought after by Dr. Lind.

2. *The vapour of nitrous acid in it's fuming ftate, or when the nitrous acid is mixed with nitrous gas.* This, though more pungent than the firft, Dr. Smyth believes may be employed with the greateft fafety, having never known any inconvenience from ufing it. But as it was more difficult to pr cure, and is attended with greater trouble and expenfe, he has always ufed the firft.

3. *The vapour of marine acid, arifing from common falt, decompofed by vitriolic acid.* This, though more ftimulating and more apt to excite coughing than the nitrous, may be fafely ufed, at leaft in a moderate quantity, where people are prefent; and where nitre cannot be had, Dr. Smyth would not hefitate to employ it.

4. *The vapour of nitrous and marine acids from nitre and common falt by vitriolic acid.* This, on being heated, was more pungent than the pure marine acid, and therefore unlefs it be found more efficacious in deftroying contagion, fhould not be ufed where people are prefent.

5. *The vapour of fulphur burnt with one-eighth part of nitre.* This can only be ufed with fafety when there are no people prefent; hence muft be folely confined to fumigating empty apartments, clothes, furniture, &c.

6. *The vapour of fulphur burnt with charcoal.* This fhould never be employed, as the carbonic acid may do harm, and never can have any effect on contagion.

7. *The vapour of oxygenated marine acid, by diftilling marine acid from manganefe.* Dr. Smyth fays, he only knows it is extremely deleterious.

Dr. Smyth found the marine acid, when properly diluted, pro. ed completely effectual in deſtroying the contagion at Winchester priſon, by waſhing the hammock poſts, wal s, and floors of the priſon ward, as well as the other furni ure with it ; and in this reſpect it is certainly more powerful than the moſt concentrated vinegar.

French che-
miſts, their
method by
marine acid
vapour. Since Dr. Smyth's experiments upon the mineral acids, the French chemiſts and phyſicians have publiſhed a paper on the means of deſtroying contagion. It is entitled, " *Inſtruction ſur les moyens d'entretenir la ſalubrité, & de purifier l'Air des Salles lans les Hôpitaux militaires de la République, ſait au Conſeil de Santé, le 5 Ventoſe, l'an 2 l de la République.*" From this *mémoire* it appears, the French phyſicians, inſtructed by Guiton of Dijon, have lately made trial of the vapour of marine acid in their hoſpitals, and have found it equally as effectual in deſtroying contagion as the ſulphureous, and, as being more volatile, perhaps even preferable for the purpoſe of purifying hoſpital wards. They alſo remark, that in a ſmaller proportion, it may be ſafely uſed in hoſpital wards, even where people are preſent, and the experiments of Dr. Smyth prove the ſame. The method the French phyſicians employed to obtain the marine acid vapour, is either by employing the fuming marine acid, or the acid detached from it's alkaline baſis by vitriolic acid, uſing a conſiderable degree of heat for this purpoſe. The proceſs for a room containing from forty to fifty beds is, after having taken out the patients and cloſed the doors and windows, to heat nine ounces of muriat of ſoda (common ſalt) ſlightly moiſtened with half an ounce of common water, and pour upon it four ounces of ſulphuric acid or common oil of vitriol, having previouſly placed the apparatus in the middle of the room. In an inſtant the ſulphuric acid acts upon the common ſalt, and the ma-

rine acid expands itfelf, the perfon taking care to leave the
room immediately, and to lock the door. In twelve hours
after, the doors and windows are to be opened to let the
currents of air evacuate the acid.

This is likewife employed in the rooms filled with pa-
tients, when there is reafon to fufpect them of containing
animal miafmata; but in thefe cafes one third part only
of the above mixture is employed, or even lefs, carrying
it into every part of the room where any infection may be
fuppofed to lurk. After the chambers are fufficiently full
of the vapour, the apparatus is put into the neceffaries or
privies, to decompofe or neutralize any bad or putrid exha-
lations they may contain.

Van Mons, in a report made to the Society of Medi- Van Mons.
cine, at Bruffels, with refpect to the means neceffary for
purifying the air in the apartments of the fick, oppofes
the method of fumigation, as it diminifhes the refpira-
ble, and adds to the unrefpirable air ; in general, he found
the air in fuch apartments to confift of abundance of car-
bonic acid, hydrogen, oxygen, and azotic gafes ; fome-
times a little ammoniacal gas, and a peculiar emanation,
called *contagious miafma*, which appears to him to be a
peculiar combination of hydrogenous carbonic acid gas,
holding in folution animal fluids very little known. The
hydrogen gas contains almoft always in folution pure
carbon, phofphorus, &c., from which the difagreeable
odour arifes. The carbonic acid would form a much
more confiderable part, according to this chemift, were
not this gas continually neutralized by the ammonia
evolved in all difeafes where animal fubftances containing
azot are decompofed. Hence the contradiction of thofe
who fuppofe air to contain carbonic and ammoniacal
gafes at the fame time, and the abfurdity of expofing vef-
fels filled with quicklime in the apartments of the fick,
which takes away the carbonic acid gas, and leaves the

ammoniacal. Among the beft means of purifying infected air, this chemift claffes vaporized water, which incommodes the patient lefs, and deprives air of it's putrid effluvia better than the muriatic or acetous acid, or than fpirits, being a better folvent than thefe. The fulphureous gas he thinks might decompofe the miafmata by giving them a portion of it's oxygen, but it leaves behind it an oxyd of fulphur, the fmell of which is very offenfive; hence oxygenated muriatic acid is preferable. (Annal. de Ch. vol. 29, p. 99.)

With refpect to the offenfive fmell of different places, fuch as privies, night-chairs, &c., an object of fuch confequence with refpect to health and comfort, the moft cheap and effectual means of deftroying it is the following: If a certain quantity of milk of lime (water in which lime has been recently flacked and poured off previous to it's fettling) be mixed with a ley of afhes, or even foapy water that has been ufed for wafhing, and thrown into the fink of a privy, or other convenience for the fick room, it will immediately deftroy the offenfive odour. It is obvious that a more fimple method is, to mix a few pounds of quick lime with a fmall quantity of wood afhes, and a bucket of water.

The fpirit of energy which the pneumatic method of confidering the caufes of peftilence has introduced, has already created a formidable oppofition againft fumigations, and the deftruction of contagion by acid vapours. Dr. Trotter informs us that feveral years ago, or in 1793, he had no faith in the fumigating procefs, and that the acid vapours, particularly the nitrous gas, muft be prejudicial to thofe who are expofed to them.

Dr.Trotter.

The offenfive effluvia, fo difagreeable to the fmell, which the acid is to deftroy, are, according to Dr. Trotter, fulphurated hydrogenous gas (hepatic gas), the aërial product of fœcal matter, and fuch as afcends from privies; phof-

phorus and carbon may alfo be mixed with it ; the nitrous
gas certainly decompounds it, and fulphur is precipitated
and the fmell vanifhes. In the fame way the nitrous acid
alters the effluvia of the confluent fmall pox, when they
approach beyond maturity ; and alfo the offenfive matter
of large floughing ulcers, which do not materially differ
from the vapours arifing from the fæcal mafs. The nitrous
gas, according to the fame author, decompofes the car-
bonic fulphurated hydrogenous gas of gunpowder fu-
migation, and takes away it's fmell ; the oxygen of the
nitrous gas combines with the hydrogen, and forms wa-
ter, and the fmall portion of azot, with the fulphur and
the carbon fufpended in the hydrogenous gas, is precipi-
tated, and the fmell difappears ; but Dr. Trotter thinks,
that the nitrous gas, when employed againft contagious
effluvia, not only adds nothing to the improvement of
the qualities of the air which fupport life, but that it is
introducing a fubftance that takes away part of the re-
maining oxygen of the atmofphere, and the different per-
fumes ufed as fumigations render the air more noxious,
by giving out hydrogenous gas. He thinks, that although
the aromatic vinegar of the Edinburgh Difpenfary, vul-
garly called the vinegar of the four thieves, is of all per-
fumes the moft grateful, yet it's effects on the atmo-
fphere cannot be great, and vinegar, which he fufpects
gives out oxygen by evaporation, had better be ufed alone.
He fuppofes, that by the fumigating procefs of Dr. Smyth,
the very fubftance is introduced which ought to be avoid-
ed, and which is the vehicle, if not the noxius caufe
itfelf (the fepton of Dr. Mitchill), and the experiments
of Reilly, Browne, and Moffat, on board different vef-
fels, he thinks have confuted the practice of it as a fumi-
gation. He looks upon the noxious gafes evolved from
excretions of the fick to be the vehicles of the infection ;
and he confiders heat as one of the moft powerful correc-

tors of contagion; it rarifies foul air, or that fpoiled by
refpiration in crowded apartments; applied to fubftances
imbibed with animal miafma, it will either diffipate it
or convert it into an inert mafs, fo as to be harmlefs; it
will dry up moifture, and above all, it is ufeful as a ge-
neral ftimulus to the body, by keeping it warm, and thus
fortifying it againft cold, which fo evidently tends to dif-
pofe it to receive infection: hence the whole prefervative
means are comprifed in the removal of the fick, clean-
linefs, fires, and ventilation. It is evident, that the opi-
nion of Dr. Trotter is the fame as that of Dr. Mitchill
refpecting the ufe of nitrous acid gas, who looks upon it
to be the moft prepofterous and ill-contrived method that
can enter the mind of man. Such are the principal me-
thods that have been employed to deftroy the putrid exha-
lations arifing from the decompofition of animal and ve-
getable fubftances, and which are called *miafmata.*

Conclufion.   *Conclufion.* There now remains to recapitulate the prin-
cipal facts, and to conclude the fubject of putrefaction.

Upon recalling to mind the principal phenomena at-
tending fpontaneous decompofition, it has been feen,
that animal matters, which are compofed of hydrogen,
carbon, oxygen, and azot, and which are often ftill more
complicated by the union of fulphur, phofphorus, &c.,
on being deprived of life, and of that conftant action
and renewal of their component parts, that appear to
conftitute it, foon begin to change by the more fimple
attractions taking place between each of their principles,
which tend to unite by pairs. This gives rife to binary
compofitions, fuch as carbonic acid, nitric acid, ammo-
nia, and carbonated hydrogenous gas, which, on being
difengaged by degrees into the atmofphere, diminifh in
proportion the mafs of animal matters. Hence it is in
confequence of this natural decompofition, that thefe
matters are obferved to become foft, to change their co-

lour, their odour, lose their texture, form and distribute
vapours and gases into the surrounding element, which serve
other bodies, particularly vegetables, with the necessary
materials for their formation ; or, under certain circum-
stances, are converted into the most deadly poisons. All
the phenomena attending the putrefaction of animal sub-
stances are derived from the above sources. From the
union of the hydrogen with the azot, arises the forma-
tion of ammonia, which has been looked upon as the
principal product of putrefaction. The combination of
carbon with oxygen, explains the formation and dis-
engagement of carbonic acid, which, on it's first discovery,
was supposed to explain all the mysteries of putrefaction.
The nitric acid, to the formation of which animal matters
are known to contribute so much in the manufactures of
nitre, arises from the union of the azot with the oxygen,
whilst a certain quantity of hydrogen gas being disengag-
ed, and carrying with it carbon, sulphur, and even phos-
phorus, is said to create that variety of putrid odours, and
that phosphorescent light observed in all animal substan-
ces during the putrefactive process.

Thefe volatile principles being united in pairs, and ex-
panded through the atmosphere, there only remains a
little carbon united or mixed with some saline matter, as
the phosphats of soda and lime. Sometimes it happens,
that even the acid of these salts is decomposed, and it's
radical seized by the hydrogen, so that nothing more is
found than the alkali or the earth which served for a basis
united to carbonic acid. These residua form a species of
earth, called *animal earth*, that often retains a little sul-
phurous and carbonated hydrogenous gas, a little oily
matter, and an extract in which the vegetable creation
finds abundance of materials necessary to their increase,
which is the reason why this animal residuum is found
to be so beneficial as a manure.

A certain quantity of water, it has been observed, is

neceffary for the putrid decompofition; according to Four-
croy, and fome of the French chemifts, it furnifhes the
quantity of oxygen for the formation of the carbonic and
nitric acids, and it contributes fingularly to the putrefac-
tive procefs, by it's affinities. They look upon the hy-
drogen likewife, arifing from this decompofition of water,
to contribute it's part in forming ammonia, fince it is a
well known fact, that when animal matters are rendered
more dilute by a large proportion of water, they afford,
during their decompofition, ammonia in great abun-
dance.

Putrefaction confifting in a fucceffion of particular at-
tractions, and forming new combinations ; it is evident,
that all exterior circumftances, as temperature, a dry or
moift atmofphere, the fituation of the matters, the me-
dium in which it is carried on, &c. will caufe a variety in
it's effects ; hence bodies that are fufpended in the air,
inhumed in the earth, or plunged in water, will undergo
various modifications in their decompofition, which will
likewife be diverfified by their quantity, their mafs, their
connexions with neighbouring bodies, and other agents,
the number and activity of which are at prefent unknown.

Hence bodies expofed to the air are foon decompofed,
or if inhumed in an ifolated ftate, furrounded by a large
quantity of earth, they are foon deftroyed, and their aeri-
form or liquid products are abforbed either by the atmo-
fphere, or the foil around them, whilft on the contrary,
when heaped together in maffes, in a deep earth that has
been faturated to excefs with the effluvia and volatile
products of putrefaction, it can no longer influence their
decompofition by it's difpofition to receive or favour the
new combinations that take place; hence they remain a
long time undeftroyed ; the animal matter is wholly con-
verted into ammonia, and a concrete oil, forming a foap,
as difcovered by Fourcroy in the churchyard of the In-
nocents.

The phenomena of decompofition of bodies plunged in water are ftill different, for in proportion as new products are formed, the water diffolves them and diftributes them into the atmofphere. A continued humidity, with a prevailing temperature of a few degrees above zero, favours the putrefaction, and the folution of thefe matters into a gafeous form ; on the contrary, a dry and hot air, by evaporating the water, dries animal bodies and converts them into mummies, in the fame manner nearly as the fands of Egypt.

Although the numberlefs varieties, which the phenomena attending putrefaction prefent to the obferver, are at prefent undefcribed, and even unknown, yet the grand purpofe to which they all tend is evident ; life, contrary to the chemical affinities which the component parts of bodies have towards each other, had forced them into organized combinations ; but being deprived of this principle, they refume again the affinities they were deprived of, and by means of putrefaction become united into lefs complex forms. This procefs, without which both animal and vegetable bodies would remain ufelefs and inert, reduces them, therefore, to the materials of which they were compofed, in order to form a new creation, and whilft it attefts the fimplicity and grandeur of the operation, it expreffes the fecundity and power which are fo well comprehended in the philofophical expreffion of Beecher, the *circulus æterni motus*, by which he meant to pourtray the never ceafing activity of nature.

Boerhaave Elementa Chem. p. 251. t. 2. — Gaber Nachricht von angeftellten Verfuchen über die Faulnifs thierifcher Safte, Hamb. Mag. t. 4. s. 484.—Joh. Bohn Differt. chymico-phys. &c. der Faulnifs. t. 2. 1685. Leips. — Ypey Wahrnehmungen über einige Faulnifs befordernde und verhindernde fubftanzen in Crell's N. E. t. 7. s. 163.—Fourcroy's Elémens de Chimie. art. Putrefaction des Subftances Animal. t. 4. — Macquer's

Wœrterbuch, art. Faulnifs.—Encyclop. Méth. t. 1. p.
79, 101, 163, 4.—Remarks on the origin of Vegetable
Fixed Alkali, with fome collateral Obfervations on Nitre,
by M. Wall, M. D Manchefter Mem. v. 2. p. 67.
1789.—M.moire fur la Nature des Fluids elaftiques
aëriformes qui fe dégagent de quelques Matières animales
en Fermentation, par M Lavoifier, Mém. de l'Acad.
1782.—Macbride's Experimental Effays. London, 1767.
Buckholz Verfuche über einige der neueften anheimif-
chen antifept. Subftanz. Weimar. 1776.—Brugnatelli
über die Faulung thierifcher Theile in verfchieden Luft-
arten, Crell's Chem. An. 1787.—Gardani, Effai pour
fervoir à l'Hiftoire de la Putrefaction. Paris, 1766.—
Nicolai de Putredine. Jen. 1769.—Crell's Verfuche über
die Faulnifs. Chem. Journ. t. 1. s. 158.—Ker's Che-
mical Dict. 1. p. p. 192. Birm. 1789.—Mém. fur les
différens Etats des Cadavres trouvés dans les Fouilles du
Cimetière des Innocens à Paris, en 1786 & 87. par M.
Fourcroy. An. de Ch. t. 5. 2d Mem. tom. 8.—Sur un
Changement fingulier opéré dans un Foie humain, Encycl.
Méth. t. 2. p. 567.—On the Converfion of animal Sub-
ftances into a fatty Matter, refembling Spermaceti, by
G. S. Gibbs, B. A. Phil. Trans. 1794 & 95.—Philo-
fophie Chimique par M. Fourcroy. Brux. An. 3. p. 126.
—Mém. fur la Nature du Cerveau & fur fa Propriété de
fe conferver long-temps apres toutes les autres Parties,
qui fe décompofent au Sein de la Terre, par M. Thouret,
Journ. de Phys. p. 329. 1791.—Macquer's Wœrter-
buch von Leonhardi. B. 7. art. Einbalfamiren.—Mé-
moire fur les Moyens de preparer les Quadrupeds & les
Oifeaux deftinés à former des Collections d'Hiftoire Na-
turelle, par M. Pinel, M. D. Journ. de Phy. fem. 2.
p. 138. 1791.—Procédé pour durcir les Subftances ani-
males, molles, pulpeufes où muqueufes, &c. par M.
Fourcroy. la Médecine éclairée.

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